

https://dspace.org/

An Investigation of Scenarios for the

Mpofu, Patience

2011-05-30
http://hdl.handle.net/10539/9960

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

An Investigation of Scenarios for the South African Platinum Industry

Patience Mpofu

A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration

Johannesburg, 2009

ABSTRACT

The platinum-mining industry is predominantly located in South Africa, which is home to more than 78 % of the world's Platinum Group Metals (PGMs). The industry has been growing extremely fast but has recently faced several challenges. High platinum prices in 2008 meant that the industry had an average return on capital of ±34 % for three to four years. This was driven by the increasing demand for PGMs, which have a wide range of industrial and high-technology applications with an important and growing impact on our daily lives. Platinum, palladium and rhodium are mainly used as a component of autocatalysts for both petrol- and diesel-engine vehicles, which together are responsible for more than 76% of net total PGM consumption. However, over the past two years, this industry has faced many challenges resulting in a significant reduction in demand for these PGMs, thereby creating many uncertainties regarding the future of the industry. The economic crisis during 2008 hurt the platinum price. It plummeted from ±US$2 200 per ounce in mid-July 2008 to approximately US$800 per ounce in late 2009, leaving some platinum mines temporarily closed.

As a result, platinum mining companies need to expand their knowledge regarding future opportunities and threats that may cause a dramatic fall or rise in the demand and supply of platinum. There is still a gap in knowledge as to how to identify the key uncertainties affecting the overall platinum industry. This research report seeks to unravel these key uncertainties. Therefore, the aim of this research is to explore the key uncertainties in the platinum-mining industry that may affect it in the next 10–15 years, and to suggest plausible future scenarios for the industry.

In recent years, strategic foresight has remained the biggest challenge associated with platinum-mining companies. Therefore, an analysis and understanding of the current and prospective status of platinum demand within South Africa and worldwide, its supply, industry trends, and key role players are critical ingredients in anticipating the future of the platinum industry. The research analysis was

therefore used to question the strategic paradigms, and to offer possible future scenarios, but not to forecast the future.

The methodology used for this study is qualitative in nature. The beliefs and thoughts of industry experts were elicited through a structured analysis of the key uncertainties identified by them regarding the platinum industry to arrive at the key ones. The respondents nominated were initially contacted by e-mail and telephone to inform them of the purpose of the study and the subjects to be covered, and to invite them to participate in the research process, including the expected timeline of the review. Upon acceptance, the draft report, with an open-structured questionnaire, was sent to the respondents by e-mail. The responses were then collated and analysed for thematic content to distil a number of key uncertainties. The key driving forces were then identified through Causal Loop Analysis (CLA) and used to posit four plausible scenarios.

The research findings showed that the two critical driving forces that defined the four scenarios were identified as, first, Global Economic Performance (GEP), that is, the performance of platinum in the global arena, and second, Emissions Legislation (EL). This legislation will be driven primarily by global warming, which will necessitate the need for more efficiency in energy use. The subsequent strategic scenarios of the platinum-mining industry were given the following names:

- Scenario 1: Sunshine Forever
- Scenario 2: Perfect Storm
- Scenario 3: Tsunami , and
- Scenario 4: Tornado

These scenarios provide a perspective of what the platinum-mining industry may have to face within the next 10 to 15 years. The scenarios confirmed that an industry is exposed to a turbulent environment when its environment is dynamic, unpredictable, and driven by continuous societal and technological change. Therefore, platinum-mining industries need to use sign-posting to plan and strategise for times of turbulence.

DECLARATION

I, Patience Mpofu, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or at any other university.

Patience Mpofu

Signed at …….

On the 10th day of February 2010

ACKNOWLEDGEMENTS

During the past three years a number of people have assisted in a variety of ways in the completion of this research project.

First, I gratefully acknowledge the personnel of Anglo Platinum, and the many platinum-industry experts for their participation and interest in this study. Second, many thanks are due to my supervisor, Dr Geoff Heald, for his guidance, encouragement and, most importantly, his patience with me.

Third, I gratefully acknowledge the unwavering support and assistance of my family and friends and especially thank my mother and sisters for encouraging me. Fourth, I want to dearly thank George Mutema for providing me with encouragement, love and support.

Finally, but most important, I would like to thank my loving son, William. It is to him that I dedicate this thesis.

CONTENTS

ABSTRACT I

DECLARATION III

ACKNOWLEDGEMENTS IV

LIST OF TABLES VIII

LIST OF FIGURES VIII

CHAPTER 1 INTRODUCTION 1

1.1 PURPOSE OF THE STUDY 3
1.2 PROBLEM STATEMENT 4
1.2.1 SUB PROBLEMS 5
1.3 SIGNIFICANCE OF THE STUDY 5
1.4 DELIMITATIONS AND LIMITATIONS 6
1.4.1 DELIMITATIONS 6
1.4.2 LIMITATIONS 7
1.5 DEFINITION OF TERMS 7
1.6 ASSUMPTIONS 7

CHAPTER 2 LITERATURE REVIEW 9

2.1 INTRODUCTION 9
2.2 OVERVIEW OF THE PGMS INDUSTRY 9
2.2.1 VALUE CHAIN ANALYSIS 10
2.2.2 STRUCTURE OF THE PGM INDUSTRY 10
2.2.3 PGM SUPPLY 12
2.2.4 PGM DEMAND 13
2.2.5 SUPPLY–DEMAND SUMMARY 16
2.2.6 INDUSTRY ATTRACTIVENESS 16
2.3 PORTER'S FIVE FORCES MODEL OF INDUSTRY STRUCTURE ANALYSIS 17
2.3.1 BARGAINING POWER OF SUPPLIERS 17
2.3.2 BARGAINING POWER OF CUSTOMERS 18
2.3.3 THREAT OF NEW ENTRANTS 20
2.3.4 THREAT OF SUBSTITUTES 21
2.3.5 COMPETITIVE RIVALRY WITHIN THE INDUSTRY 22
2.4 PGM INDUSTRY CHALLENGES 23
2.5 THE SCENARIO PLANNING MODEL 28
2.5.1 HISTORY 28
2.5.2 STRATEGY UNDER UNCERTAINTY 29
2.5.3 WHY SCENARIOS FOR THE PLATINUM INDUSTRY? 32

CHAPTER 3 RESEARCH METHODOLOGY 33

3.1 Methodology Employed 33
3.1.1 Determination of the key uncertainties and interconnections: A qualitative research paradigm 34
3.1.2 Descriptive research design 35
3.1.3 The scenario development process 37
3.1.4 Selection of the scenario planning model 38
3.1.5 Implications of the scenarios 39
3.2 Population and Sample 39
3.2.1 Population 39
3.2.2 Sample and sampling method 40
3.3 Procedure for Data Collection 41
3.4 Data Analysis and Interpretation 41
3.4.1 Summary of steps taken 42
3.4.2 Building a causal loop diagram 43
3.4.3 Constructing scenarios based on the causal loop diagram 44
3.4.4 Evaluation of the scenarios 44
3.5 Validity and Reliability 44
3.5.1 External validity 44
3.5.2 Internal validity 45
3.5.3 Reliability 45

CHAPTER 4 PRESENTATION OF RESULTS 46

4.1 Introduction 46
4.2 Scenario Exercise Parameters 46
4.3 Demographic Profile of Respondents 47
4.4 Summary of Relevant Key Driving Forces 47
4.5 Analysis of Key Driving Forces 47
4.5.1 Causal loop analysis: Identification of the major uncertainties 51
4.5.2 Legislation on emissions control 53
4.5.3 Global economic performance 53
4.6 Scenario Construction 54
4.7 Description of the Scenarios 55
4.7.1 Sunshine Forever: High Global Economic Performance and Rapid Increase in Emission Legislation 55
4.7.2 Tornado: High global economic performance coupled with slow emissions legislation 57
4.7.3 Tsunami: Low global economic performance coupled with slow emissions legislation 58
4.7.4 Perfect Storm: Low global economic performance and increased emissions legislation 60

CHAPTER 5 DISCUSSION OF THE RESULTS 63

5.1 Introduction 63
5.2 Discussion: Platinum Industry Scenarios 63
5.3 Conclusion 66

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS 68

6.1 INTRODUCTION 68
6.2 CONCLUSIONS OF THE STUDY 68
6.3 RECOMMENDATIONS 69
6.1.1 SCENARIO SIGNPOSTS 70
6.4 SUGGESTIONS FOR FURTHER RESEARCH 72

REFERENCES 73

APPENDIX A: LETTER TO REQUEST EXPERT REVIEW 83

APPENDIX B: QUESTIONNAIRE TO EXPERTS.....84

APPENDIX C: RESPONSES 85

APPENDIC D: CONSISTENCY MATRIX 105

LIST OF TABLES

Table 1: Levels of Uncertainty and Strategic Responses (Courtney et al. 1997) . 31

Table 2: List of Respondents 40

Table 3: Criteria for evaluation of scenarios (Kipps 2007) 66

Table 4: Signposts for the Platinum-Mining Industry 71

LIST OF FIGURES

Figure 1: Simplified PGM activity chain from mining through to end-use 10

Figure 2: Industry structure overview (Jollie 2009) 11

Figure 3: Platinum-mining industry cluster 12

Figure 4: Projected platinum supply per region (Jollie 2009; Davis 2009) 13

Figure 5: Platinum (left) and Palladium (right) demand based on 2008 figures (Jollie 2009) 14

Figure 6: Platinum supply and demand from 1999–2008 (Jollie 2009) 16

Figure 7: Key driving forces grouped according to level of uncertainty and impact 51

Figure 8: Causal loop diagram of the key driving forces for the platinum industry 52

Figure 9:Proposed platinum-mining industry scenarios 55

Figure 10: Using foresight for strategic decision making (Gordon 2008) 65

CHAPTER 1 INTRODUCTION

South Africa is the source of more than 78 % of the world's Platinum Group Metals (PGMs) (Creamer Research 2007). The country's platinum mines converge in one of the biggest metals-bearing intrusions in the world, namely the Bushveld Igneous Complex (BIC). The BIC covers over 66 000 km^2 and is divided into an eastern and a western limb, with a further northern extension, known as the northern limb. It has a series of distinct layers, three of which contain economic concentrations of specific PGMs, namely iridium (Ir), osmium (Os), palladium (Pd), platinum (Pt), rhodium (Rh), gold (Au), and ruthenium (Ru). Three mining houses account for the majority of the supply of platinum to the global marketplace. These are Anglo Platinum, Impala Platinum, and Lonmin, all located in South Africa, with approximately 80 % of the market share (Creamer Research 2008; Engelbrecht et al. 2007; Wilburn and Bleiwas 2007).

Due to all-time high platinum prices in 2008, the industry had an average return on capital of ±34 % for three to four years (Creamer Research 2008). This was driven by the ever increasing demand for the PGMs, which have a wide range of industrial and high-technology applications with an important and growing impact on our daily lives. They are mainly used as components of autocatalysts for both petrol- and diesel-engine vehicles, which together are responsible for more than 76 % of the net total PGM consumption. Pt, Pd, and Rh are the most prevalent in the reef ores of the BIC, and contribute the most significant percentage in terms of revenue (2007 figures) (Clarke et al. 2008). Pt alone contributes from 42 % (Platreef) to a high of 55 % (Merensky Reef) (Clarke et al. 2008), hence the common practice of referring to Pt rather than a basket of all PGMS from both a demand and supply perspective. As will be seen in later chapters, Pt has a higher demand than other PGM metals, and commands a much higher price owing to its wider uses.

Extensive research has been done on the future of platinum in its various applications but particularly in fuel-cell technology (Andres 2002; Garland and Milliken 2002; Watts et al. 2008; Genc 2008; and Yang 2009). Some authors predict that fuel cells have the potential to represent a very significant source of demand

post-2015 (Andres 2002). Substantial fuel-cell demand continues to lie some way in the future, yet the need to start developing hydrogen infrastructure will arise earlier, and progress could be compromised by a lack of confidence in future platinum supply (Nel 2004). The evolutionary path from petrol/diesel internal-combustion engines to fuel cells remains unclear and could lead to volatile demand profiles over a number of years. Owing to tighter environmental legislation globally, and increased industry activity especially in fast-growing economies such as China, the high demand resulted in a supply deficiency and very high platinum prices, particularly during 2008 (Loferski 2008). Uncertainties regarding the security of electricity, energy and water have created a declining confidence in the capacity of the South African Government to deliver infrastructural requirements.

On 25 January 2008, nation-wide electricity black-outs occurred, which resulted in outrage among all South Africans. The mining houses (and PGM mining in particular) were not spared; indeed they were the hardest hit, resulting in all their operations being forced to stop for almost two weeks. Many executives asked themselves, “How did this come about?” Did they fail on the side of strategic planning for the company, or was it simply a case of ignoring some important signals? Some mining houses are still questioning whether the power black-outs will continue in the future. Such questions will haunt executives of many a company whenever there is such a crisis. The impact of the electricity outages was evidenced by the fall in production by ±20 to 30 % in the platinum industry. This not only resulted in the highest platinum price ever, namely >US$2 000, but also created widely publicised fears of whether South Africa would be able to meet the demand for platinum in the future, given that it is the dominant supplier world-wide (Hill 2008; Genc 2008; Stillwell 2008). Delayed increases in new supply resulted in sustained high prices, thereby damaging the risk factor and user confidence, as well as long-term demand for platinum.

As though the electricity blackouts were not enough, later in September 2008 the world was plunged into a global financial crisis that impacted negatively on virtually every industry (Duncan 2009). The mining industry was not spared, as the economic crisis hurt every commodity price. Platinum prices plummeted from

±US$2 200 per ounce in mid-July 2008 to approximately US$800 per ounce in late 2009 (GFMS 2009). The global automotive industry, for instance, witnessed sharp declines in new vehicle sales. As a result, a depressed demand for platinum and, in essence, reduced credit availability meant shelving or delaying many platinum mining projects (GFMS 2009).

This type of unpleasant surprise renders most executives of companies highly uncomfortable. Hence organisations are finding it increasingly difficult to plan for the future. Not only do organisations need to function (and survive) in these turbulent conditions; they also need to plan for the future, take investment decisions, and attempt to gauge how they will perform in the coming years. In low-uncertainty situations, standard budgeting and forecasting tools can be used for planning. The current environment, however, require scenario planning. Standard budgeting and forecasting tools are inadequate for turbulent situations, which are highly uncertain, complex and volatile (Genc 2009). It is these key uncertainties that this research report seeks to unravel in order to create plausible future scenarios for the platinum industry.

Scenario planning is a tool that organisations can use to help them imagine and manage the future more effectively by trying to make sense of the complexity and uncertainty in which they have to make decisions. The scenario process highlights the principal drivers of change and associated uncertainties facing organisations today, and explores how they may play out in the future (Godet 2000; Fahey 2003; Kahn 1967). It is important to look at plausible scenarios for the platinum-mining industry for the next 10 to 15 years.

1.1 Purpose of the Study

The above indicates that shock events can have a sudden impact on the platinum-mining industry. The environment in which we live and work is constantly changing. It is against this background that this research aims to explore uncertainties in the current platinum-mining industry to gain insight into the probably state of the industry in ten to fifteen years' time. There are currently challenges in the global

economy and hence numerous potential risks exist that may cause a dramatic fall in the demand for and supply of platinum (Yang 2009).

Platinum mining companies therefore need to expand their knowledge of future opportunities and threats. Despite extensive research conducted on the future of the platinum industry (Andres 2002; Bruce and Das 2002; Garland et al. 2002; Gilreth et al. 2003; Chevalier 2004; Nel 2004; Watts et al. 2008; Genc 2008; Smith et al. 2008; Yang 2009), there is still a paucity of knowledge in identifying and dealing with the key uncertainties in the overall platinum industry (without focusing on the fuel-cell future alone) and arriving at plausible future scenarios. It is clear that this is where research is required, particularly when one takes into consideration the power crises that faced the South African economy in 2008 and, more important, the impact of the global economic crisis.

The aim of this report is therefore to develop a set of plausible future scenarios for the platinum industry, based on a time frame of 10 to 15 years. This research report seeks to explore certain questions on the current platinum-mining industry. What shifts in the platinum industry could change the whole industry structure in 10 to 15 years' time? Will the platinum industry be able to navigate the waves of another turbulent, global economic crisis (or double-dip recession) and will there be profound implications for platinum demand as a result of the development of a hydrogen economy or, alternatively, downside-enhanced competitiveness from battery-powered, electric cars?

1.2 Problem Statement

In light of the background sketched above, the current status is that platinum mining companies need to expand their knowledge regarding future opportunities and threats. Hence this research seeks to explore the key uncertainties of the platinum-mining industry that would affect it in the next ten to fifteen years and posit future plausible scenarios for the industry. The scenario analysis questions strategic paradigms and offers possible futures, but does not forecast the future. This study will also include identifying the implications for the platinum-mining industry.

1.2.1 *Sub problems*

Questions that emerge are as follows:

- What are the key uncertainties of the platinum-mining industry that will impact on the industry in the next ten to fifteen years?
- What are the future plausible scenarios for the platinum-mining industry in the next ten to fifteen years and the implications thereof?

1.3 Significance of the Study

South African mining companies were entering a global upstream sector as, internationally, the demand for platinum was surging until late in September 2008 (Crisp 2005; Stillwell 2008; Watts et al. 2008; Genc 2008). Platinum prices plummeted from US$2 200 per ounce in mid-July 2008 to approximately US$800 per ounce, thereby hurting most platinum mining companies.

In the light of this, strategic foresight remains the biggest challenge that is uniquely associated with platinum-mining companies (Smith et al. 2008). Therefore, analysis and understanding of the current and prospective situation of platinum demand, supply, industry trends, and key players are critical ingredients in understanding the future of the platinum industry (Andreas 2002; Watts et al. 2008, Yang 2009). The ever-changing world poses numerous threats and opportunities for the platinum mining players (Yang 2009).

This research report places emphasis on two aspects of significance. First, from an academic point of view, there has been limited research of this scope and in this field to date (Smith et al. 2008; Watts et al. 2008). Secondly, over 50% of *Fortune 500* companies and others across the globe apply scenario planning in their future strategy management (Godet 2000). A set of meaningful foresights and scenarios is generated in this research, which should therefore make a significant contribution to the platinum-mining business practice and related literature. As scenario planning is not very commonly used in the South African mining business, the nature of this

research will link up with the current uncertainties in the corporate world and thus test the scenario-planning technique (Schoemaker 1995).

Although some researchers have used a combination of a robustly mixed methodology by combining scenario planning with Delphi and Fuzzy Cognitive Mapping techniques, this research offers a step forward in the use of scenario methodology in the platinum-mining industry (Kipps 2007). From a business perspective, this research has important implications because of the key uncertainties and other issues facing the platinum-mining industry today. As discussed above, the mining environment has recently been faced with several unexpected challenges. Moreover the future of platinum is uncertain because of the predicted demise of the internal combustion engine, and the subsequent rise of new technologies, such as the electric vehicle, diminishing the demand for autocatalysts. This research should therefore deliver some insights as to the 'what and how' the companies may be faced with in 10 to 15 years' time. The results of this report indicate where platinum mining companies should and could be focusing their strategies in the next few years – a topic of interest to practitioners, industry analysts and consultants, as well as partner organisations. The future trends identified by the experts could form the basis for more in-depth research in the future.

1.4 Delimitations and Limitations

1.4.1 *Delimitations*

The objectives of this research report are to explore the key uncertainties and to suggest plausible future scenarios for the platinum industry. The research does not include other issues and uncertainties pertaining to the entire South African mining industry. Moreover the research does not attempt to formulate comprehensive common strategies for all platinum-mining companies. It only identifies the key uncertainties and four scenarios, and describes the implications of those scenarios. International experts were included in the list of participants. However, the study is

only applicable to platinum-mining industries within South Africa, or whose operations are based in South Africa

1.4.2 *Limitations*

The limitations of this research process include the fact that the sample comprises those whom the researcher perceives as experts in the area of the platinum industry and no tests were done to verify the randomness of the sample.

1.5 Definition of Terms

Scenarios: Tools for ordering one's perceptions about alternative future environments in which one's decisions might be played out (Schwartz 1991).

PGMs: Platinum Group Metals

Thrifting: A frugal industry practice that can bring significant savings and, in the context of this research, reduction in PGM loadings in the autocatalyst.

Fuel Cell Technology: This technology converts hydrogen and air into electricity and water using a platinum catalyst.

1.6 Assumptions

The following assumptions underlay the research:

- The panel of experts had enough knowledge about the platinum-mining industry to be able to identity key uncertainties.
- The relatively large sample ensured that no inherent bias would result from the profile of the selected respondents.
- The methodology used ensured that the results produced are reasonable and consistent.

- A common list of uncertainties can be generalised across the platinum-mining industry in South Africa.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Some research has been done on the future of PGMs in fuel cell technology (Andres 2002; Bruce and Das 2002; Garland et al. 2002; Gilreath et al. 2003; Chevalier 2004; Nel 2004; Yang 2009). Despite these studies, there is still a paucity of knowledge about the key uncertainties of the overall platinum industry and plausible scenarios for the next 10–15 years.

This chapter presents a literature review focused on an overview of the platinum-mining industry, scenario planning and the current state of knowledge on the key uncertainties on the future of the platinum industry.

2.2 Overview of the PGMs Industry

South Africa is the world's largest producer of PGMs, with over 4.5 million ounces of Pt produced in the country in 2008 of the total global supply of ±5.97 million ounces. This represents over 76 % of global supply, the balance coming from Russia, North America and other smaller suppliers (Jollie 2009). South African resources of PGMs are highly concentrated, in the Bushveld Igneous Complex (BIC).

The BIC contains the world's largest known platinum deposit and covers an area of approximately 65 000 km^2 in the northern provinces of South Africa. The BIC was formed by repeated injections of magna into a massive underground chamber. In simple terms, this magna cooled and crystallised over millions of years, forming a layered deposit as different minerals crystallised at different temperatures during the cooling process. Subsequent intrusions repeated the crystallisation sequence and through this process, like minerals were deposited together (Wilburn and Bleiwas 2007; Creamer Research 2007). The PGMs (Pt, Pd, Rh, Ru, Ir, and Os) formed in two layers, the Merensky and the UG2 reefs, which also contain high quantities of Gold, Nickel, Copper and Chrome. A third platinum-bearing deposit is also mined towards the north of the complex and is known as the Platreef. The Great Dyke is a

layered intrusion similar to the Bushveld Complex, running south-west through the centre of Zimbabwe. The Great Dyke is estimated to contain 9% of the world's platinum resource (Wilburn and Bleiwas 2007). The reef is thus called the Main Sulphide Zone (MSZ).

2.2.1 Value chain analysis

Extracting these valuable PGMs is an intrinsic and very highly capital intensive process from mining through to processing and finally fabrication before the final product goes to the customers. Platinum deposits can be mined through either underground or open pit mining. Once mined, the ore is concentrated, which is an initial process to separate waste from the PGM-rich ore, thereby increasing the concentration of PGMs for treatment in the next phase. The next phase is smelting, which comprises drying the ore, then melting it under very high temperatures. The resulting matte is then refined in the base metals refinery where base metals such as nickel and copper are chemically removed. The final stage is the removal of PGMs and gold in a predefined sequence. The refined PGMs are then sent to the fabricators as either ingots or in powder form (Anglo Platinum Annual Report 2007). The summarised PGM activity chain is shown below in Figure 1.

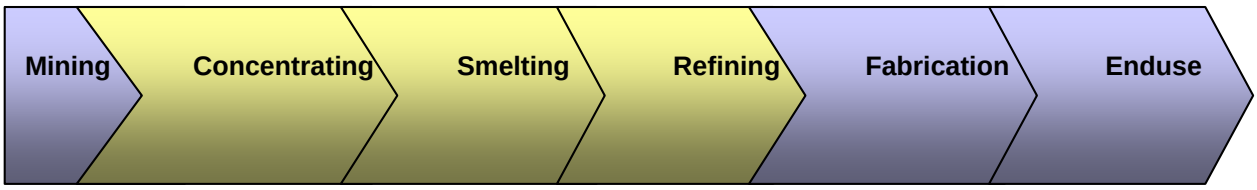


Figure 1: Simplified PGM activity chain from mining through to end-use

2.2.2 Structure of the PGM industry

The PGM industry structure is highly concentrated, with 80% of the world's PGMs coming from the Bushveld Complex in South Africa (Loferski 2008). The major suppliers, which account for over 76% of platinum supplies, are Anglo Platinum, Impala Platinum and Lonmin (Jollie 2009). Figure 2 below shows a more detailed

industry structure overview. The end-use figures shown are based on the 2008 demand figures quoted in the Johnson Matthey 2009 Market Review Report.

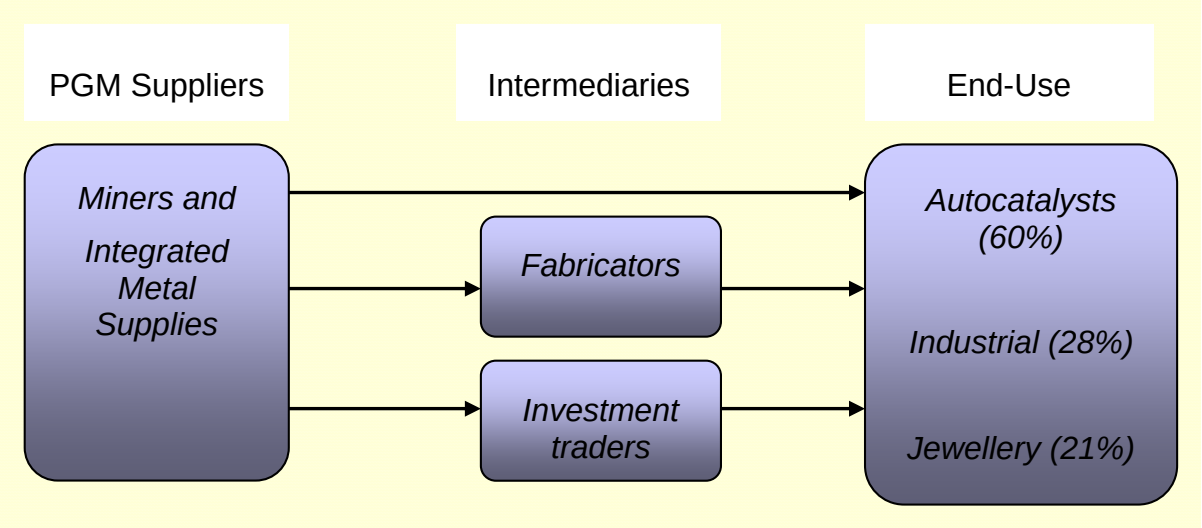
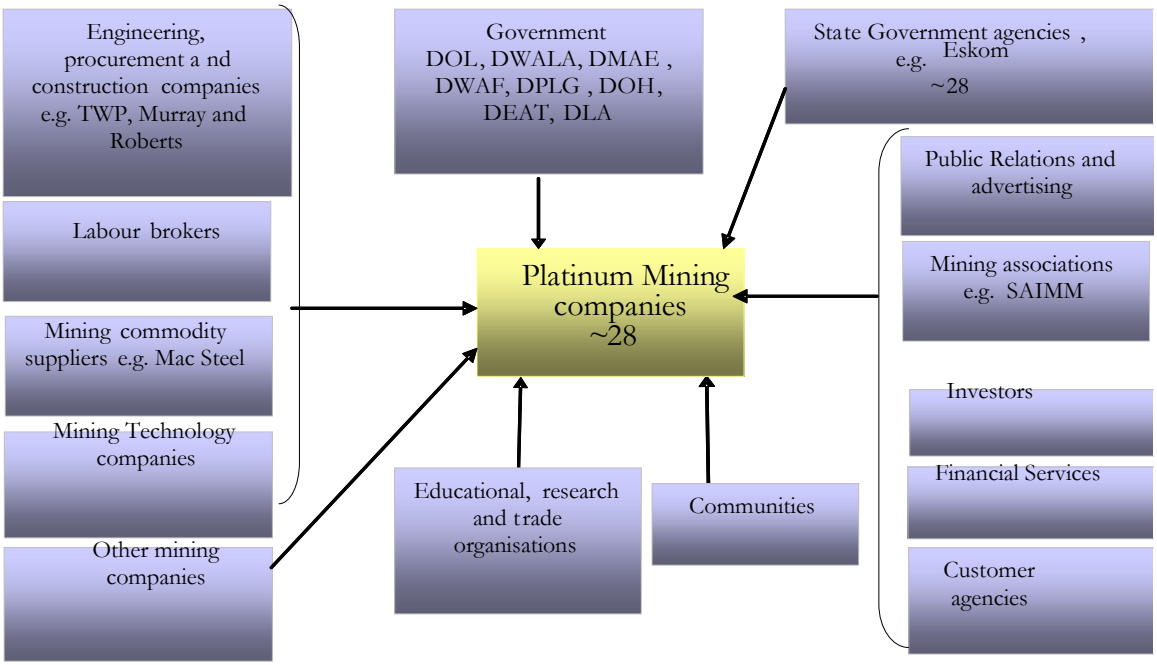


Figure 2: Industry structure overview (Jollie 2009)

Figure 3 shows an overview of the platinum-mining industry cluster. There are about 28 platinum-mining companies including the three main companies noted above. The industry is supported by an extensive complement of industries, including engineering and construction companies such as TWP, Murray and Roberts, and Hatch, institutions such as the Australian Mining and Industry Associations (AMIRA), South African Mining and Mineral Industries Associations, and universities such as the University of Cape Town, and WITS University. There are also linkages with Government, particularly the Department of Minerals and Energy for the conversion of mining rights, the Department of Water Affairs, and the electricity parastatal Eskom for energy supply. Competition and cooperation is promoted within the cluster, e.g. for skills and project management services, which is currently one of the key challenges within the mining industry.



(DOL: Department of Labour: DWALA: Department of Water and Land Affairs: DWAF: Department: DOF: Department of: DEAT: Department of DLA:

Figure 3: Platinum-mining industry cluster

2.2.3 PGM supply

Figure 4 shows the supply by region over the last 10 years (Jollie 2009). The main player in Russia is Norilsk. It is clear that South Africa is blessed as the world's largest producer of platinum hence any constraints on South Africa's socio-political environment can have a significant impact on the global PGM supply (Yang 2009). In 2008, all three major platinum-mining houses recorded lower output than in 2007 due to various factors such as bad weather, safety shutdowns, industrial unrest and skills shortages, and the major factor – chronic power outrages (Genc 2008; Jollie 2009, Yang 2009). The result of this was volatility in the platinum price with a high of ±US$2500/oz from US$1530/oz in the first half of the year. The price remained at that high level until the global economic crisis became apparent in October 2008, when it crashed to a low of US$756/oz (Genc 2008; Jollie 2009). It is also anticipated that the industry will see an ever-increasing secondary supply into the market in the future. Davis (2009) believes that platinum recovered from autocatalyst recycling could double to over two million ounces over the next five years. Figure 4 shows a ±4.5% drop in South African supply in 2009, due mainly to

restructuring of production, costs, and capital projects; an 8.5% rebound in 2010; and projected growth of around 2.5% annually thereafter (Davis 2009).

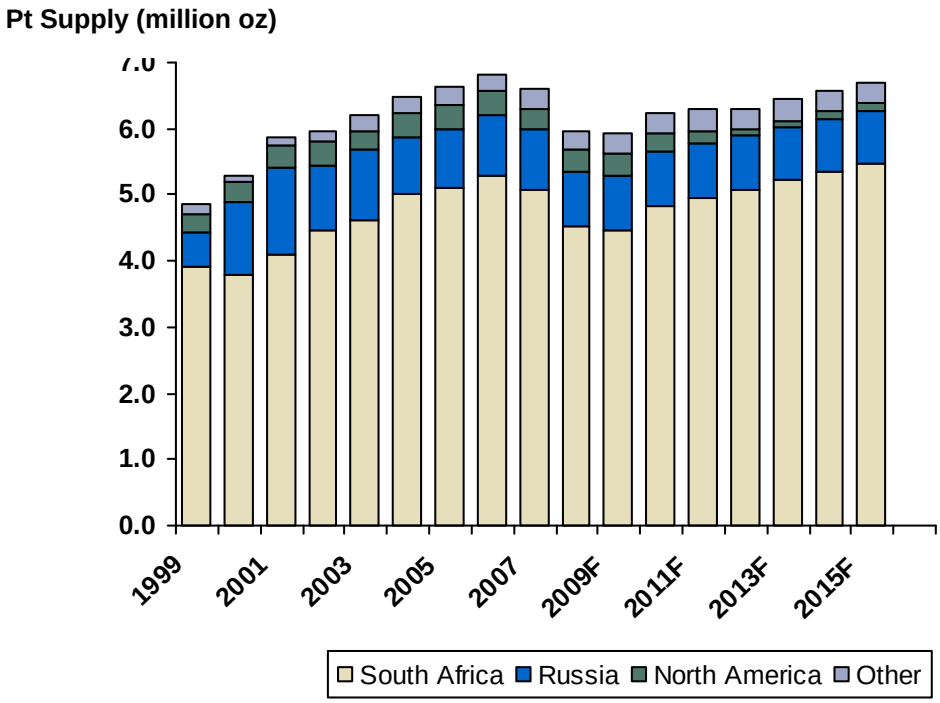


Figure 4: Projected platinum supply per region (Jollie 2009; Davis 2009)

2.2.4 PGM demand

PGMs are generally used in applications which depend strongly on their unique properties, such as inertness, with excellent corrosion- and oxidation-resistance, biocompatibility, a high melting temperature, good conductivity and electronic and catalytic properties (Jollie 2009; Watts et al. 2008). They have a wide range of industrial and high technology applications that have an important and growing impact on our daily lives. Platinum has the widest range of applications of all PGMs. Its main uses are as a component of autocatalysts, for both petrol- and diesel-engine vehicles, which together are responsible for more than 44% of net total Pt and 47% of net Pd consumption, as shown in Figure 5 (Jollie 2009). Autocatalysts are used in the exhaust systems of vehicles to reduce emissions to the environment, such as carbon monoxide. Petrol-fuelled vehicles typically use a three-way catalyst, so-called because it converts three pollutants, carbon monoxide

(CO), hydrocarbons (HC) and oxides of nitrogen into carbon dioxide, water and nitrogen. Diesel engines require a diesel oxidation catalyst to remove CO and HC, and can also reduce particulate matter by up to 50%. PGMs form the active components in all of these autocatalysts, as platinum, palladium and rhodium offer remarkable resistance to high-temperature corrosion and oxidation.

PGMs were first employed in catalysts in 1974, in preparation for the US's Clean Air Act. At that time, these catalysts primarily used platinum. Europe only began using autocatalysts in the early 1990s, as the debate around global warming and the contribution of harmful vehicle emissions to this phenomenon intensified, and emissions regulations tightened (Stillwell 2009). Today, around 90% of all new petrol cars being built contain autocatalysts, also called catalytic converters. However, as diesel passenger cars have gained in popularity, fast trains have also become subject to increasingly stringent emissions regulations (Stillwell 2009).

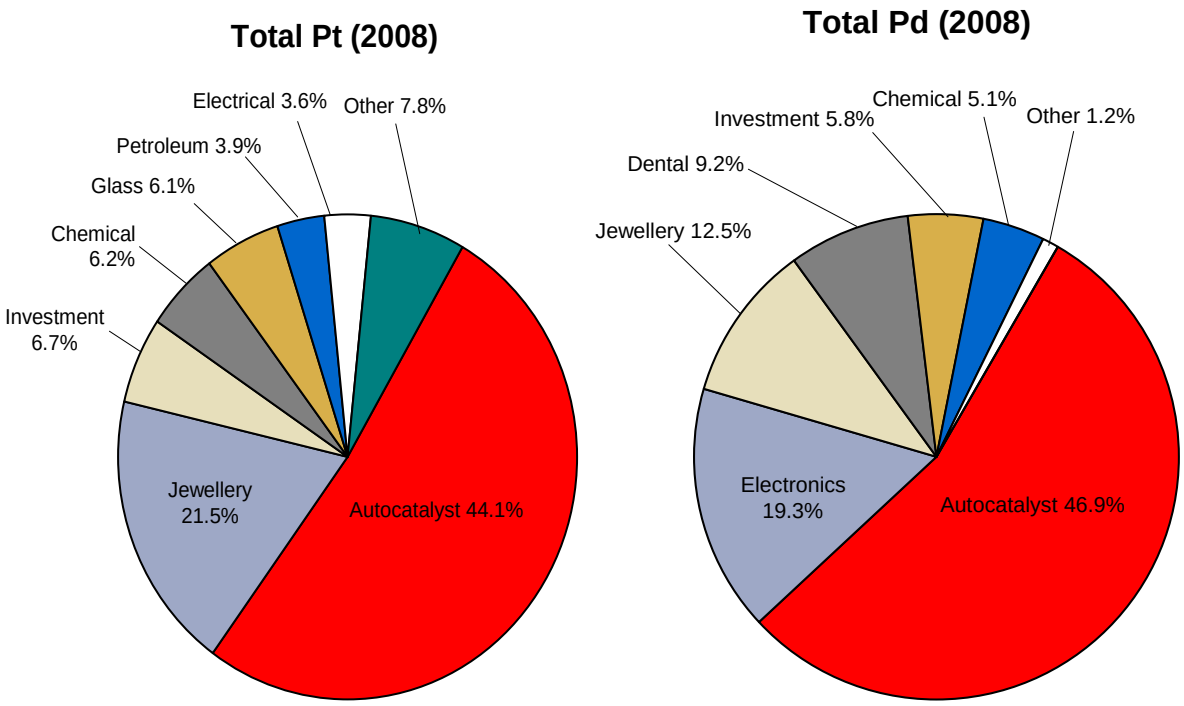


Figure 5: Platinum (left) and Palladium (right) demand based on 2008 figures (Jollie 2009)

As can be seen in Figure 5, their outstanding catalytic properties make platinum and its associated group of metals an indispensable component of catalytic converters for controlling automobile emissions and of catalytic electrodes in hydrogen fuel

cells. It also plays essential roles in the production of various chemicals, silicones, computer hard drives and flat panel display glasses. Hence most of the PGMs produced are consumed by industry rather than stored in coffers. The global demand for platinum has consistently outgrown supply in the past decade (Yang 2009; Jollie, 2009). Several factors contributed to this demand. Firstly, car sales have been growing worldwide, especially in developing countries. Secondly, developing countries are becoming more stringent in tightening their emission standards, hence automobiles must be equipped with advanced catalytic converters, which require higher loadings of platinum. Thirdly, in the face of high oil prices and global warming, European countries are switching to diesel vehicles for their high fuel efficiency (Watts et al. 2008). Diesel vehicles are now equipped with filters and two-way catalytic converters and these require an even higher loading of platinum than three-way converters (Watts et al. 2008).

Autocatalysts have helped lower auto-emissions by an estimated 12 billion tonnes of harmful gases that would otherwise have entered the environment (Andres 2002). However, Pt also has an enormous range of lesser known applications, predominantly in the chemical, electrical, jewellery, medical, glass and petroleum industries. It is alloyed with gold, silver and copper for dental uses. Alloys of Pt with other PGMs are also used in chemotherapy, particularly to fight leukaemia, and to make biomedical devices. An alloy of Pt and Os is used in pacemakers to regulate heart function and in heart replacement valves (Watts et al. 2008; Jollie 2009).

Other PGMs such as Pd also have principle applications in autocatalysts (around 47% of net production in 2008) (Jollie 2009). It is anticipated that Pd may gain a bigger share in autocatalyst use as demand is expected to grow based on the fact that Russian stocks are almost depleted and increased use in smaller vehicles in China and India (Jollie 2009). Pd is also used in electrical components, including multi-layer ceramic capacitors and in dental alloys (George 2006). Rh is also used in nearly 85% of catalytic converters for the auto industry. Small amounts are also consumed in industrial applications such as glass-making.

2.2.5 Supply–demand summary

A Johnson Matthey analysis of the supply and demand numbers from 1999 particularly for platinum shows that demand for this metal has historically been outstripping supply (Jollie 2009). In 1999, as part of the restructuring process of its state-owned business, Russia suspended its PGM export for most of the year and this created a ±10% shortage in global platinum supply. In general thereafter, platinum demand has outstripped supply almost every year, resulting in increased price volatility (Jollie 2009). Recycled platinum has been excluded from these figures.

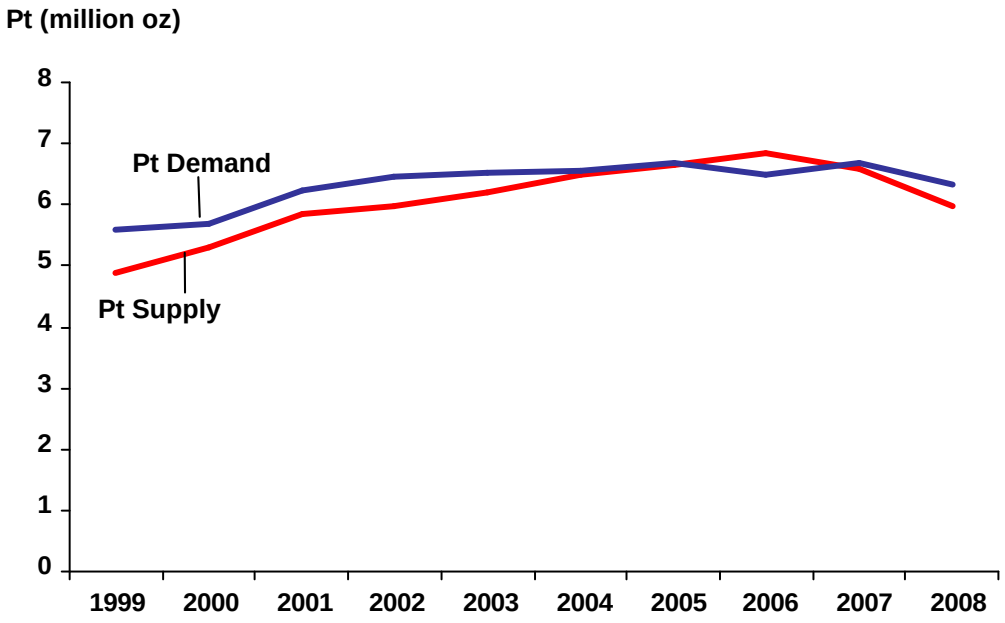


Figure 6: Platinum supply and demand from 1999–2008 (Jollie 2009)

2.2.6 Industry attractiveness

Despite the steep decline in vehicle sales, and therefore catalyst demand, as a result of the 2008 global economic crisis, the industry remains attractive for several reasons. Firstly, due to tighter environmental legislation globally and increased industry activity especially in fast-growing economies such as China, demand is expected to increase as the global economy starts recovering. It is also reported that the fitment of platinum-based after treatment on heavy duty diesel vehicles, in order to meet tightening legislation, will increase as well (Engelbrecht and Anderson

2008; Davis 2009; Jollie 2009). Jewellery demand also contributes as it tends to increase with a decrease in price (Jollie 2009). In addition, the fact that PGMs have a wide range of end-use applications suggest sustainable long-term demand growth. Investment (Exchange Traded Funds) also plays a part. On the other hand, a high platinum price drives more thrifting and substitution of platinum particularly in the autocatalyst sector. In the gasoline sector, there has been increased use of palladium catalyst formulations instead of platinum-based technology. It is also anticipated that there will be an increase in Pt-Pd catalysts rather than Pt-only catalysts (Bloxham 2009). Together, it is anticipated that these trends will restrict growth in platinum demand in the medium term (Bloxham, 2009; Davis, 2009). There are also new technologies such as the electric vehicle, which might diminish the demand for autocatalysts. On the other hand, technological advances in fuel cells may give rise to an insatiable demand for PGMs in the future. Research shows that this will be the locus of demand growth for PGMs as most countries go green (Bloxham 2009; Watts et al. 2009; Yang 2009).

2.3 Porter's Five Forces Model of Industry Structure Analysis

The model of the Five Competitive Forces, developed by Michael Porter (1985), is an important tool for analysing an industry and is based on the insight that a corporate strategy should meet the opportunities and threats in an organisation's external environment. The Five Competitive Forces are typically: the bargaining power of suppliers, the bargaining power of customers, the threat of new entrants, the threat of substitutes, and competitive rivalry within the industry. This method of analysis is applied here to the PGM mining companies.

2.3.1 Bargaining power of suppliers

Suppliers into the platinum-mining industry are already having a major impact on the industry. A major example is the specialised engineering, procurement and construction companies such as TWP and Murray and Roberts. Supplier bargaining power is quite high because the cluster is dominated by these few large suppliers and there are no substitutes for the high-tech engineering mining shafts that these

companies provide. Moreover the high returns enjoyed by the mining companies are not necessarily also enjoyed by the supplying industry, and as input costs have escalated the threat from this area has increased. The mining shafts are crucial to the platinum business, hence security of supply can be threatened. Skills requirements is another issue facing all mining companies. It would be prudent for the companies to build stronger stakeholder relationships with each other and bargain collectively. A very strong unionised labour force creates a strong bargaining position for labour, which constitutes high input costs to the industry (Genc, 2009). Artisans are a critical skill in all areas of mining operations and the supply of artisans in South Africa is in decline.

Water supply is also becoming a constraint and is insufficient for the platinum industry's current operations. Regarding electricity, the planned portfolio of new power generation projects is unlikely to meet future demand levels in time, as seen in Eskom's recent load shedding in the mining industry (Genc, 2009). Hence relationship building with suppliers is becoming prominent in the industry. Availability of sufficient project resource capacity internally and in the marketplace is critical to the successful implementation of capital projects. This also applies to the accessibility of shaft sinking capacity and the procurement of critical commodities.

2.3.2 Bargaining power of customers

The bargaining power of customers describes how much customers can impose pressure on margins and volumes (Porter, 2008). PGMs, as already noted, have several applications, and the demand for these products differs depending on the market segment (Garland and Milliken, 2002). In the case of autocatalysts, switching to an alternative product is not an option, and customers cannot produce the PGMs themselves, hence the PGMs are of strategic importance to them. This means low bargaining power for them. In addition supply is mostly based on long-term contracts (typically five years), with prices set by the market. Looking at the demand of these contracts gives an indication of the bargaining power of customers. Gross demand for platinum for autocatalysts is forecast to grow slowly (Jollie, 2008). Growth arises through vehicle growth (primarily in developing markets) and new technology requirements arising from the broader application of

legislation (for example diesel particulate filters) (Jollie 2009). Further, tighter emissions legislation (in 2008) will increase the incremental cost of diesel engines beyond fuel efficiency savings (Davis 2009). The US government is continuously looking to decrease CO_2 emissions from motor vehicles via the Energy Policy Act 2005 (Crisp 2005; Bloxham 2009). In addition, stricter legislation coming into force in Europe in 2014 will focus on reducing NO_x emissions from diesel vehicles, thus requiring the use of additional catalytic after-treatment. Given the considerably higher quantities of PGMs used in diesel after-treatment than in gasoline after-treatment, any increase in the share of diesel engines will lead to greater demand for PGMs. The potential impact of additional incentives to drive diesel penetration is significant. This demonstrates that net platinum demand is dominated by the autocatalyst sector and driven by environmental legislation, which gives producers the competitive advantage.

Platinum demand for industrial usage satisfies a broad range of applications. This promotes relatively price-inelastic demand and the threat of substitution is relatively low (Jollie 2009). Some demand may be more price elastic – for example new data storage applications in electronics – but in general for industrial usage this is not the case. Glass demand is forecast to decrease, as a result of the current surge in demand for new capacity to make glass for LCDs, with future net demand tempered by the recycling of platinum installed for aging technology (Jollie 2008). Fuel cells represent one source of considerable potential future growth post-2015 (Watts et al. 2009). However the evolutionary path from petrol/diesel internal combustion engines to fuel cells remains unclear and could lead to volatile demand profiles over a number of years (Chevalier, 2004).

Platinum jewellery represents a high proportion of consumer spend in China and Japan. Research into the jewellery market (Jollie, 2008) shows that global platinum jewellery consumer demand is estimated to have grown at 8% compounded growth since 2002, in line with overall consumer spend in key platinum markets. Future platinum jewellery demand will be driven by macro-economic growth, increasing consumer disposable incomes, and consumer propensity to purchase platinum jewellery; when the platinum price is low consumer spend in jewellery seems to

increase. Overall, the continued market demand and supply is forecast to remain robust in the long term for platinum and to firm up for palladium (Crisp 2005; George 2007; Wilburn and Bleiwas 2007). In summary, fabricators are consolidated and tend to influence the market and in addition, there are consolidated end-uses. The diverse use of PGMs is a counter cyclical one to the other implying that when PGMs prices are high the demand in one application may be low but when they are low the demand may be high in another application.

The above shows that the PGM industry enjoys a broad portfolio of end-use applications and this diversity should provide sustainable long-term demand growth, which reduces the bargaining power of customers. Moreover, since the industry fabricators are highly concentrated, suppliers appear to be price-takers, reducing their bargaining power.

2.3.3 Threat of new entrants

If the competition in an industry is high, it is easier for other companies to enter this industry. In such a situation, new entrants could change major determinants of the market environment (e.g. market shares, prices, customer loyalty) at any time. There is always a latent pressure for reaction and adjustment for existing players in the platinum industry. The threat of new entries will depend on the extent to which there are barriers to entry (Porter 2008). There is a scarcity of important resources, such as qualified expert staff and access to raw materials, which are controlled by existing players. Capital requirements such as start-up costs are very high in the platinum-mining industry, particularly access to processing technology and the subsequent long lead times for platinum projects. In addition, high fixed labour costs present a challenge for new entrants.

Government policies have of late been made favourable to new entrants into the platinum industry and are more difficult for existing platinum mining companies especially those mining companies that did not comply with the Mining Charter requirements. The Department of Minerals and Energy requires all mining companies to convert their old mining rights to new mining rights. The new mining rights have several BEE scorecards that the companies have to comply with before

they can be granted the new licences to mine/operate. New entrants to the platinum industry have increased because of joint ventures even amongst big competitors such as Lonmin. The fact that 80% of PGMs resources and reserves are found in Southern Africa limits new entrants from other regions, but may present an opportunity for a national PGMs company, for which there have been increased calls from some government quarters (Watts et al. 2009)

2.3.4 Threat of substitutes

A threat from substitutes exists if there are alternative products with lower prices or better performance parameters for the same purpose. They could potentially attract a significant proportion of market volume and hence reduce the potential sales volume for existing players (Porter 2008). So far in the auto catalyst market, there has not been any successful adoption of non-Pt-based fuel cells applications that could threaten Pt price increases. Ongoing research is taking place into clean mobility in the future, stringent emission legislations, oil crises and alternative sources of energy (Garland and Milliken 2002; Chevalier 2004; Nel 2004).

The fuel cell technology, which is Pt-based, can only make the platinum industry even more attractive. Fuel cells are being mentioned in every other *Fortune* or *Time* magazine these days (Yang 2009). So far, the fuel cells developed are Pt-based and a non Pt-based alternative is yet to be found. The evidence is that as a result of the USA's hydrogen initiative, global demand for all fuel cell products (portable, stationary and transportation applications) will reach US$46 billion per year by 2012 and over US$2.5 trillion per year by 2021 (Andres 2002; Crisp 2005). So far the Honda FCX hydrogen fuel cell car has been proven and tested and Toyota has the FCHV fuel cell hybrid vehicle. All this is due to the car manufacturers' drive to be the environmental leaders in zero emissions and the fact that a substitute which is not Pt-based is far from being reached (Honda website, 2007). The above all points to a low threat of substitutes for platinum.

However, there are still some uncertainties surrounding fuel cell technology and these are hydrogen storage (larger volumes vs. current required), huge costs, and refuelling technologies. Thrifting is happening in the autocatalysts sector but there

are also counter-effects due to continuous changes driven by legislation, which requires increases in PGMs loadings. Recycling and secondary supply are also a substitution threat. Autocatalyst recycling is expected to double to ±2 million ounces over the next five years (David 2009). Other authors forecast the secondary supply of platinum from spent autocatalysts to more than double by 2018 from ±880 000 ounces in 2010 to 2 030 000 ounces in 2018 (Jollie 2009). An ever-increasing secondary supply of platinum into the market is likely to have an effect on the supply dynamics.

Growth of green/electrical vehicles with no PGMs loadings could be another substitute with a potential threat to the platinum industry (Yang 2009). However, a number of authors predict that this is still far in the future (Yang 2009; Jollies 2009). Substitution of platinum in autocatalysts is growing but another PGM, palladium, is being used in its place. An encouraging outlook for palladium usage in this sector is forecast as emerging economies become the largest vehicle producers. Autocatalyst demand is projected to rise some 20% between 2008 and 2012 and autocatalysts should remain the mainstay of palladium demand over the next ten years, making up a steady 60% of consumption (Watts et al. 2009). In the jewellery market, a threat for substitute has already taken place with platinum jewellery being replaced by palladium and white gold, which are much cheaper. The sustained price differential between platinum and palladium has emphasized the qualities of palladium in both new and existing industrial applications as well as in jewellery. However, the jewellery sector only represents a portion of the total market for PGMs (Jollie 2009).

2.3.5 Competitive rivalry within the industry

This force describes the intensity of competition between existing players in an industry. Highly competitive pressure results in pressure on price margins hence on profitability for every single company in the industry (Porter 2009). Competition between the current platinum players is not very high because there is not much differentiation between the companies and their products, and therefore no price

competition. The major competitors are all stable and represent ±80% of global supply (Jollie 2009).

2.4 PGM Industry Challenges

There are currently challenges in the ever-changing global economy and numerous potential risks, as well as new beneficiation pressures worldwide, which may cause a fall in demand and supply. From a demand perspective, several authors predict that fuel cells have the potential to represent a very significant source of demand post-2015 (Andreas 2002; Garland et al. 2002; Chevalier 2004; Crisp 2005; Jollie 2008, 2009). However, some authors consider that substantial fuel cell demand is still some way into the future, as the need to begin to develop hydrogen infrastructure arises much earlier, and progress could be compromised by a lack of confidence in future platinum supply (Yang 2009; Bloxham 2009).

Yang (2009) further states that the evolutionary path from petrol/diesel internal combustion engines to fuel cells remains unclear and could lead to volatile demand profiles for a number of years. Moreover, due to tighter environmental legislation globally and increased industry activity, especially in fast-growing economies such as China, the demand for platinum might be higher, resulting in supply deficiency and high platinum prices. This could lead to significant thrifting or the seeking of substitutes.

There is already strong evidence of increased use of alternatives. At first, it was not very expensive to use platinum in catalyst production, until the price of the precious metal started to rise from around $360/oz, in 1999, to more than $1 980/oz, in 2008. Platinum recycling from catalytic converters started as early as the late 1970s, as soon as escalating prices made it economically feasible. It didn’t take the automotive industry’s research and development departments long to seek a cheaper substitute, which they found in palladium (Watts et al. 2009). The current palladium price is around $240/oz. The substitution of palladium for platinum was one of the first moves to shake the PGM market. Palladium is already a full-on substitute for platinum in petrol autocatalysts, but still only a partial substitute in

diesel autocatalysts (Bloxham 2009). Today, vehicle manufacturers worldwide are working towards cutting the use of all types of PGMs in catalytic converters to the minimum, and finding a less expensive substitute, which will mean far less demand for platinum if they are successful (Yang 2009). Given the need for the industry to continually reduce costs wherever possible, and the potential for new technologies to enter the catalyst market, there are notable risks to platinum's dominance. However, as emerging markets are more price sensitive it is possible that companies will want to make the direct leap to the new-generation, lower-priced catalysts (Watts et al. 2009).

PGM substitution in the global automotive industry may eventually affect the PGM industry (Andreas 2002; Watts et al. 2009). The 2009 drop in vehicle production certainly influenced PGM demand (Watts et al. 2009). For platinum, the bulk of the loss was attributed to the slump in global vehicle production, combined with the continuing effects of thrifting and its substitution by palladium in both diesel and petrol applications (Watts et al. 2009).

Gold has been researched as one alternative option. In 2009, at prices of around $870/oz, the yellow metal was much cheaper than platinum. In December 2007, the World Gold Council, which aims to improve global gold demand, announced that it had agreed to a long-term partnership with a US company, Nanostellar, to enable the introduction of gold in the auto catalyst market. Nanostellar has developed a product that uses gold, alongside platinum and palladium, in an auto catalyst (Watts et al. 2009). This can reduce emissions by up to 40% more than the platinum catalysts used in diesel-engine applications. However, platinum experts argue that this technology still requires some platinum and palladium, adding that gold remains much more expensive than palladium.

Almost at the same time, the Nissan Motor Company, in Japan, announced that it had developed a petrol-engine catalyst for its Cube compact car that uses half the platinum, palladium and rhodium used by existing technology. Nissan developed the technology in collaboration with French vehicle manufacturer Renault. Then late in 2008, another Japanese company, Mitsui Mining & Smelting, announced that it had developed a new catalyst for diesel-engine cars that replaces platinum with silver –

again the argument being one of cost. The company argued that by substituting platinum with silver, the cost of precious metals in the production of autocatalysts could be cut by more than 90%. Emissions regulations for heavy (diesel) vehicles would become increasingly tighter from 2012, creating a tantalising market for Mitsui's innovation.

With between 40% to 50% of the world's PGM production used in the automotive industry, the impact of any technological breakthrough that completely substitutes PGMs carries the potential of unravelling market fundamentals. The question is timing – how close are vehicle manufacturers to hauling new emissions technology from the laboratory to the production line, and should PGM producers start to worry about the impact of this on the PGM market? More than 100 years after the invention of the motor vehicle, there are other issues to consider rather than just emissions reductions. For example, could the rise of the electric vehicle diminish the demand for autocatalysts, should the challenges regarding the uptake of fuel cells persist? 1

In early 2009, Mazda announced that it would launch the first market application of single-nanocatalyst technology in automotive catalytic converters later in the year (Watts et al. 2009). The company explained that this would reduce the use of PGMs in autocatalysts by 70%. Earlier, other vehicle manufacturers, such as Honda, used something called perovskites (crystalline ceramics) to replace PGMs; however, this experienced some durability problems. Daihatsu Motor Company has been working on developing a platinum-free fuel cell car (Watts et al. 2009). However, the tightening emissions standards in countries such as China and India, lagging European standards by a generation or two, may provide some counterbalance for the substitution threats platinum is facing.

From an investment demand perspective, two Exchange Traded Funds (ETFs) were launched in London and Zurich, which are backed by physical platinum and palladium. Demand in this sector rose drastically from 2007 through to 2008 as the price rose (Jollie 2009). In early January 2009, the USA launched another ETF at the New York Stock Exchange. This sector is also very dependent on global economic conditions. The PGM industry analysts are betting on the strong emerging

markets of China and India, where vehicle ownership is rising, but emissions legislation lacking, to counter any potential drop-off in demand. Already the PGM industry has survived a 50% cut in the use of these metals in autocatalysts. Moreover, the extension of legislation to cover retrofit, off-road vehicles and motorcycles will further boost demand (Watts et al. 2009). The automotive market takes up around 55% of global PGM supply, 60% of palladium, and 85% of rhodium supply. Moreover some authors believe that attempts to find alternatives for PGM-based catalytic convertors have not been successful due to PGMs' unique catalytic properties and superior durability while operating in the extremely hostile environment of an internal combustion engine (Yang 2009). The threat emanating from new technologies to replace the internal combustion engine, such as electric cars, does not seem to achieve the main thrust of global environmental legislation to lower emissions (Davis 2009). It is reported that electric vehicles simply move the emissions from one source to another (Bloxham 2009).

A leading German chemical company (BASF) predicts that the penetration of the electric vehicle by 2020 will be between 5% and 20% of the global market, depending on oil price developments, and incentives and policies to encourage the introduction of these vehicles (BASF 2009). As the oil price rises, there is a stronger argument for electric cars, which use no fuel. Toyota company announced late last year its first battery-powered vehicle but at the same time called for calm in-order to manage expectations. The company further alluded that if consumers are disappointed, market adoption may not be guaranteed and that could permanently harm the technology's image and future market potential. Hence, for the next decade, the use of catalytic converters may not be growing. For gasoline- and diesel-powered combustion engines BASF does not expect any technology to overtake the catalytic converter. They report that hybrids will not reduce PGM demand, as these vehicles use a combination of a battery and a standard internal combustion engine, and the use of a combustion engine requires the use of a catalytic converter (Jollie 2009, Watts et al. 2009, Bloxham 2009). In fact, in many cases the catalysts used in hybrid electric battery / internal combustion engine vehicles use more PGMs (Watts et al. 2009).

From reported studies (Bloxham 2009; Watts et al. 2009), it appears that the only true emission-free technology is the fuel cell. This technology converts hydrogen and air into electricity and water using a platinum catalyst. It currently uses considerably more platinum than a conventional catalytic converter (Andres 2002; Bruce and Das 2002; Gilreath et al. 2003). However, fuel-cell technology uptake may be slow, due to the lack of hydrogen-refuelling infrastructure for these fuel cells, as well as issues regarding cost and the limited driving range. Therefore some authors report that they do not foresee new vehicle technologies having any impact on the South African mining industry (Andres 2002; Bruce and Das 2002; Gilreath et al. 2003).. There have been a number of these 'breakthroughs' in the past 20 years, but all have proved unsustainable for one reason or another. It remains to be seen whether Mazda's technology, for example, will be restricted to the Japanese car maker.

The uncertainties described above all present challenges to the platinum industry in the future, mainly from the demand side. There are also uncertainties from the supply side around security of energy and water supply. These have already created declining confidence in government's capacity to deliver infrastructural requirements. This was evidenced by the fallen production of some 20-30% in the platinum industry, due to the power crisis, which not only created the highest platinum price ever (>US$2000), but caused widely publicised fears of whether South Africa would be able to meet demand in the future as the dominant supplier (Hill 2008; Genc 2008; Stillwell 2008). Delayed increases in new supply resulted in sustained high prices, damaging user confidence and long-term demand.

Mining industries are invariably cyclical, with major variations in price of output, prices of capital equipment, exploration costs, resource acquisition costs, and permitting and development costs. Timing is a crucial source of competitive advantage: from a supply perspective, the timing of mine acquisition or capital goods acquisition, and from a demand perspective, the timing of contracting, such as price, duration, and adjustment clauses (Stillwell 2008).

From the above analysis, it appears there are a lot of challenges but also possibly opportunities for the platinum mining companies. Such challenges and opportunities

seem to be uncertain, particularly in terms of timing. Hence it will clearly be beneficial to analyse the key uncertainties that may have an impact over the next 10–15 years. These uncertainties include supply challenges; electricity, water and skills constraints; sensitivity to global economic conditions; and technology changes as described above – these questions keep haunting many stakeholders particularly executives of the platinum-mining companies. For example: will China and India be able to maintain robust economic growth and provide a corresponding increase in their demand for platinum in the long term? What shifts regarding technology will guarantee a robust PGM demand? To what extent will the ETFs affect price volatility and long term supply into the market? What role will secondary supply play in the future? What surprises could be in store for PGM mining companies in the next 10–15 years? These give rise to the first research question.

Research Question 1: **What are the key uncertainties for the platinum-mining industry that will impact on the industry over the next 10–15 years?**

2.5 The Scenario Planning Model

2.5.1 History

The concept of scenarios dates back to the sixties when it first appeared in Kahn's work (Godet at al. 2000). In the mid-eighties, scenario planning became even more popular with the Harvard Business Review's publication of the Shell success story in the scenario planning written by the late Pierre Wark. Since the late eighties, scenario planning has continued its course with the networking activities of Pierre Wack and Peter Schwartz, (Schwartz 1991, 1996, 2005; Godet et al. 2000; O'Brien 2002). Scenario planning is concerned with envisaging possible futures and exploring strategies for organisations to thrive even in times of risk and uncertainty (Coates 2003). Scenarios are archetypal, detailed narrative descriptions/images of models of plausible (coherent, internally consistent) possible future states (Godet 2000). They do not claim to predict, but rather represent alternative perspectives on the future, for the purposes of informing current decision-making and planning processes (Kahn 1967, 1973; Wack 1985; Schwartz 1991; the Futures Group 1994;

Shoemaker 1995; Rothmans and van Asselt 1998; Greeuw et al. 2000; Godet 2000, 2000b; More 2003; Bradfield et al. 2005; Selin 2006). Scenario planning examines internal and external factors, particularly environmental uncertainties, to give managers a view of what might take place in their environment in the future. Scenarios assist strategists and managers in understanding the potential futures and thus making robust strategic decisions under uncertainty. However, despite being thoroughly described in the literature by practitioners, scenario planning faces challenges as an academic methodology. Multiple methodologies and interpretations of the scenario process are described in the literature, ranging from highly intuitive unstructured methods (criticised by some as methodologically fuzzy), to rigorous rationalist probability-based methods (rejected by other authors as contrary to the stated goals and theoretical underpinnings of scenarios) (Schoemaker 1992, 1995; Coates 2003).

The analysis of environmental factors dates back to earlier literature on strategic analysis, such as Porter's emphasis on the five forces analysis (Porter 1995). However, in the rapidly changing environment that many companies find themselves in today, a scan of forces in the external environment raises more uncertainties than answers, especially over the long term. In order for organisations not to be paralysed by this uncertainty, there is a need for some search for clarity on the strategic options available, to ensure continued development (Godet 2000). This is the realm of strategy under uncertainty (Miller and Waller 2003).

2.5.2 Strategy under uncertainty

We live in a world that is constantly evolving, and yet within this evolution history seems intent on repeating itself. This paradox has been driven by our continued use of history as a source of experience to improve ourselves, but also by our remarkable refusal at times to learn from it. Interestingly, our world has remained relatively predictable in one aspect for the last few centuries. The West has been the dominant force in global politics and economics – a veritable superpower apart from the former Soviet Union.

But the game has changed quite dramatically over the last three decades, with the emergence of new, and highly influential, players answering to different rules while tilting the global playing field their way. First came the re-emergence of Japan, then the arrival of the Asian tigers and now the ascent of China. All in all, we are at a significant moment in the long time-frame of human history because real change is happening before our eyes. One prominent American industrialist said: "I feel like the British did 100 years ago. America is still good at producing missile guidance systems, but how many of these can you sell compared to fridges and cars where the expertise has moved elsewhere?"

Researchers argue that the future is determined by a multitude of forces, including social and political forces (post-modernisation, terrorism, political shifts, post-materialism), scientific discovery, natural forces and revolutionary technological innovation, new business processes, and new philosophies (Glenn 1994; Mercer 1995; Coates 2000; Neilson and Stouffer 2005). The degree of uncertainty inherent in the future is determined by the degree of uncertainty inherent in these external forces. Uncertainty derives from sources such as innovation, unprecedented events, chaos and chance, systemic changes, and errors in observation and forecasting (Gordon 1994). Uncertainty also derives from the complex interactions of uncertainties and changes – aptly captured by Mercer's (1995) wave analogy: "separate waves of progress interact unpredictably with one another to create major new discontinuities in the organisational environment".

The future is highly unpredictable. However, organisations can use foresight to help free up their thinking beyond the here and now to explore plausible alternative futures (Sunter 1998; Sunter and Ibury 2008). When an organisation has been around for a long time and its way of life and working is so entrenched that it is hindering the company from adapting to changes and competing, it is then necessary for a company to create problems to initiate that culture change. Companies need to develop this set of tools to understand the key driving forces and critical uncertainties in order to take control of their business future. Scenarios not only incorporate all the other forecasting techniques, but also allow for uncertainties by examining alternatives rather than offering a single forecast

(Chermack et al. 2001; Cornelius et al. 2005). Due to an increase in innovation, creativity has been recognised as one of the essential characteristics for long-term success (Chermack 2003). Situations can either be certain and predictable to a precise degree, lending themselves to traditional planning, or they can be such that the future is unknowable and managers cannot plan. A lot of work has been done on strategic responses (Schoemaker 1995, 2002; Coates 2000; Courtney et al. 1997; Godet at al. 2000). Different levels of uncertainties have been categorised to identify the appropriate strategic responses for each (Courtney et al. 1997).

Table 1: Levels of Uncertainty and Strategic Responses (Courtney et al. 1997)

Level of	Description	Strategy Mechanism
Level 1: A clear enough future	Low uncertainty. Managers can develop a single forecast that is sufficiently clear for strategy development.	Standard tool – research, value chain analysis, Porter's five forces, discounted cash.
Level 2: Alternative futures	A number of discrete possible futures can be described, and strategy would change under each. For example, industries facing major regulatory change.	Scenario, real options, decision analysis, probability analysis, etc. Scenarios describe the discrete possibilities.
Level 3: A range of futures	A range of possible futures exists along a continuum, defined by a number key variables or uncertainties. Typical in industries driven by technological innovation, and emerging industries.	Scenario planning, technology forecasting. Scenario is more difficult to create. Besides the extremes, they are not discrete.
Level 4: True ambiguity	Even the variables that will determine the future are uncertain: the interaction of variables is not clear: future is almost impossible to predict. This level is rare and tends to move to other levels over time	Modelling (what is known), quantitative analysis by pattern and analogy.

2.5.3 Why scenarios for the platinum industry?

Business activity is concerned with the future. Indeed, the terms “far sighted”, “forward thinking” and “good foresight” have long been attached to successful managers. Based on the above literature review, it is clear that the uncertainties facing the platinum industry point to a Level 3 of uncertainty. Hence the creation of plausible future scenarios for the platinum industry is warranted. This has prompted the following research question:

Research Question 2: **What are the likely plausible future scenarios for the platinum-mining industry?**

A thorough analysis of the literature has revealed that the evolutionary path from petrol/diesel internal combustion engines to fuel cells remains unclear, while tighter environmental legislation globally and increased industry activity, especially in fast-growing economies such as China, could lead to volatile demand profiles over a number of years (Andres 2002; Bruce and Das 2002; Garland et al. 2002; Gilreath et al. 2003; Chevalier 2004; Nel 2004;, Watts et al. 2009; Bloxham 2009; Yang 2009). There is still a gap in knowledge regarding the key uncertainties of the overall platinum industry (not just the future of fuel cell technology) and deriving plausible future scenarios. It is these key uncertainties that this research report seeks to unravel in order to create plausible future scenarios for the platinum industry over the next 10–15 years.

CHAPTER 3 RESEARCH METHODOLOGY

Given the research problem stated in Chapter 2, which concerns plausible scenarios for the platinum-mining companies, this research is more qualitative in nature with minor quantitative aspects. According to Leedy and Ormond (2001), all forms of qualitative research have two things in common: the focus is on phenomena that occur in natural settings and the phenomena are studied in all their complexity and multiple facets. The present study thus has the typical characteristics of qualitative research. The purpose of the research is to describe and explore. The research process has the potential to reveal unknown key uncertainties and several possible realities may be constructed by different individuals. Moreover, scenario analysis is said to start with an emphasis on qualitative analysis, to retain the focus and freedom of thought, but increases emphasis on quantification in later phases, creating formal models to effectively depict complex systems, separating the elements for analysis and understanding (Futures Group 1994). In that sense, the nature of this research is exploring and pioneering, based on phenomena that occur in complicated natural settings.

3.1 Methodology Employed

This section describes the methodology employed in the research process. Industry experts' beliefs and thoughts were elicited through a structured analysis of the key uncertainties and the relationships between them were constructed by the use of the Causal Loop methodology. A combination of the two techniques was used for reasons that will be evident with the analysis of each technique in the following sections.

3.1.1 Determination of the key uncertainties and interconnections: A qualitative research paradigm

This study is intended to arrive at plausible scenarios for the platinum mining companies, hence the research paradigm for the study is qualitative in nature. The intent of qualitative research is “to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participants’ point of view” (Leedy and Ormond, 2001). A number of distinguishing characteristics exist between quantitative and qualitative research (Leedy and Ormond, 2001). The research paradigm is informed by these characteristics. The defining characteristics include the purpose of the research, the nature of the research process, methods of data collection, the form of reasoning used in analysis and the manner in which the findings are communicated (Leedy and Ormond, 2001).

Given the characteristics of a qualitative paradigm as described by Leedy and Ormond (2001), a qualitative approach was proposed for several reasons.

- The purpose of the research is to describe and explore,
- The variables are unknown,
- The research is context bound and encompasses personal views,
- The samples size is small, and
- In-depth semi-structured interviews are to be used to collect data.

Certain assumptions are embedded in qualitative research. These must be considered throughout the research process. The following qualitative paradigm assumptions inform this research (Creswell 1994):

- The relationship of the researcher to that researched is “researchers interact with that being researched”,

- The nature of reality is that “reality is subjective and multiple as seen by the participants in a study”,

- The language of the research is “informal, evolving decisions, personal voice, and accepted qualitative words”.

3.1.2 Descriptive research design

The design of the research is descriptive and can be classified as idiographic. Idiographic research is “concerned with exploring particular cases or events and providing the richest picture of what transpires (Cornfold and Smithson 1996). More specifically, it is proposed that qualitative design takes the form of a content analysis. Leedy and Ormond (2001) describe content analysis as “a detailed and systematic examination of the contents of a particular body of material for the purpose of identifying patterns, themes, or biases”. In this research the content analysis was carried out on the transcripts of the interviews which took place between the researcher and the respondents.

As alluded to the above, in-depth semi-structured interviews were used as the method of data collection. The interview was based on two open-ended questions (Leedy and Ormond 2001). This method of data collection was suggested as it allows for the flexibility required from the evolving nature of the research problem, and it is appropriate for research problems (such as the one dealt with here) which require in-depth discussion and probing. Advantages of using in-depth semi-structured interviews for data collection include:

- Respondents can “provide historical information” (Creswell 1994).
- The researcher has control over both the questions asked and the environment.
- It provides a large amount of useful information (Leedy and Ormond 2001).
- It is flexible and enables the researcher to prompt and probe as necessary.
- It enables the researcher to take cognisance of non-verbal behaviour.

Despite its many advantages the researcher is aware that skill and care is required in using this method of collecting data. What is more, there are several disadvantages associated with this method of data collection (Creswell 1994). These are as follows:

- Information provided by the respondent is coloured by their own perspective.
- The researcher's presence may bias responses.
- Not all people are equally articulate and perceptive, and data may be misinterpreted by the researcher relative to the intended meaning of the respondent.

The researcher attempted to mitigate some of these disadvantages by: continuously confirming with the respondent the intended meaning of their response, not leading the respondent, and avoiding colloquialisms and ambiguous words.

One other method that has been used by several practitioners for scenario analysis is the Delphi method (Loo 2002; Powell 2003). This method was considered by the researcher initially; however due to several disadvantages, the qualitative method was selected instead. Some of the disadvantages related to the Delphi technique are documented in the literature (Story et al. 2000). These include insufficient reliability, oversensitivity of results, and difficulty in assessing the degree of expertise (of the panel experts). Other authors concede that the technique pressurises the panellists towards conformance rather than consensus. Delphi studies run the risks of respondent fatigue, and increased time and cost. (Powell 2003).

The main advantages of the Delphi technique are that it aims to maximise the benefits of an expert panel's consideration of an issue while simultaneously minimising the potential negative aspects of group decision-making such as domination by powerful individuals or professional interests inhibiting honest responses. However, it was considered that these positives were outweighed by the negatives, hence the method was eventually not used in this study.

3.1.3 The scenario development process

There is no one correct way of constructing scenarios, although common themes do appear in the literature (Alcamo 2001, 2005; Roux 2009). May (1996) summarises the major procedural steps in the construction of scenarios as follows:

- Identify the central concerns of the users of the scenarios. What are the key decisions that will need to be made or the key issues involved? Ask the right questions.
- Identify the development or driving forces that are likely to have the most important influences on the central concerns in the future. These should include scientific or technological developments, political, economic and social changes, or anything that could have a major impact on the central concerns.
- Analyse these important driving forces. Where can they be reasonably predicted and where are the main uncertainties? This step is useful in identifying the areas where more research is needed into the factors affecting the central concerns and where major unknowns remain and uncertainties are unavoidable. Schwartz (1991) stresses the need to look for the main trends and the trend breaks, which are particularly difficult to find but are often critical.
- Assess the importance and the uncertainty of the driving forces for the central concerns. The identification of two or three such critical factors is useful in the next stage of defining the central themes of the scenarios, since they could be important in bringing about quite different futures.
- Selection of the scenario logics, the main themes or assumptions around which the scenarios are to be constructed, is crucial. Schwartz (1991) suggests that it is important to end up with a few scenarios whose differences make a difference to decision-makers. Themes that seem likely to lead to clearly different future situations are the most useful.
- Develop the scenarios, usually in the form of narratives that present a plausible sequence of events. They should centre on the impact of each of

the scenario themes on the driving forces identified earlier. A balance needs to be struck between detail and ease of understanding. As outlines, scenarios are not intended to cover all events and one or two pages should therefore be sufficient. Anything longer is difficult for users to understand.

- Analyse the impact of the scenarios on the key concerns with which the process began. This may reveal common themes that seem likely in the different circumstances envisaged by the scenarios, help identify robust decisions that will probably remain relevant in different situations, or stress the need to monitor volatile and uncertain situations.
- Analyse the implications for policy and identify indicators that will help monitor changes as they occur. A series of questions can be useful at this stage, such as “Do certain decisions seem more likely to be successful in different circumstances while others appear to depend on only one set of circumstances?”

There is no firm agreement on the number of scenarios that should be prepared (Aligica 2005; Roux 2009). To provide alternatives, there should certainly be more than one, but to avoid overload there cannot be too many. Published work has shown different numbers of scenarios (Tonn 2005). Three is a common number, but there is always the danger that unless they are very carefully constructed, one will be seen as the middle and most likely option, and the other two rejected as extremes, in which case the purpose of developing the scenarios is lost.

3.1.4 Selection of the scenario planning model

The unpredictable complexity and uncertainty of the future platinum industry require strategy foresight through scenario thinking. All traditional business forecasting or market research methods are important; however the scenario planning model can provide better strategic insight into plausible platinum scenarios. The generated key uncertainties were used as key inputs for creation of the plausible scenarios of the platinum-mining industry.

3.1.5 Implications of the scenarios

Step-by-step, the research developed a set of plausible scenarios, which was used as comprehensively as possible to ensure a thorough analysis of the implications for the current platinum mining companies. Note that the scenarios do not yield solutions themselves and must be considered in association with strategic implications.

3.2 Population and Sample

3.2.1 Population

The population for expert review can be considered to be all the strategy consultants, mining analysts (interested in platinum stocks), and business executives who have an interest or stake in the strategy of platinum-mining companies. The sample drawn was purposive, consisting of a panel of experts selected for their experience, researchers who had done related work before, and executives of platinum-mining companies, who have the authority to give insight into the issue under investigation (Story et al. 2001). The success of a qualitative study largely depends on the expertise of the expert panel – its size and the qualifications of experts (Powell 2003). For the purpose of responding to the questionnaire, and giving feedback on the draft report, the researcher considered the above stated group to be representative and sufficient.

The sample design is purposive in that, the researcher purposefully selected respondents who have the required experience to answer the research questions (Creswell 1994). Furthermore, the objective was to select experts who are representative of the population, and who were expected to give normal perceptions and perspectives (Leedy and Ormond 2001). No attempt was made to select respondents randomly (Creswell 1994).

3.2.2 Sample and sampling method

The researcher used a panel of 18 experts, which is considered sufficient for a study of this nature (Story et al. 2001). The sample size was limited by the availability of experts in the area due to certain players being occupied by the global economic crisis that had impacted on their companies. The sample size was also determined by the concentration and specialisation of platinum mining experts and their availability in the timeframe. Representatively, two top-rated mining analysts, eight senior executives and managers from platinum mining companies listed on the JSE Securities Exchange, two strategy consultants from top consulting firms with experience in the platinum-mining industry and six researchers and experts in scenario planning and the platinum industry, some of whom are members of the International Platinum Association (IAP), were selected as the sample. Table 2 below shows the details of the members of the panel.

Table 2: List of Respondents

Position of individual	Company name
Mining Analyst	Credit Suisse
Mining Analyst	BJM
Strategy Consultant: Mining	McKinsey
Strategy Consultant: Mining	McKinsey
Head: Strategy and Business Optimisation	Anglo Platinum
Head: Mineral Resource Management	Anglo Platinum
Head: Market Research and Development	Anglo Platinum
Senior Planning Analyst	Anglo Platinum
Senior Planning Analyst	Anglo Platinum
Planning Analyst	Anglo Platinum
Business Development Manager	Lonmin
Head: Investor Relations	African Rainbow Minerals
Researcher	University of Cape Town (UCT)
Director/Economist	Stellenbosch University (IFRS)
Researcher	University of the Witwatersrand (Wits)
Scenario Expert	Consultant
Scenario Expert	Consultant
General Manager: PGM Industry Expert	Johnson Matthey (Plc)

3.3 Procedure for Data Collection

The criteria for the literature reviewed were defined by the author as referring to the platinum-mining industry, especially the future context. Documentation such as journal articles, conference papers, newspaper articles, brochures, memoranda, reviews and formal reports were used as sources of data.

The respondents nominated were initially contacted by email and telephone to inform them of the purpose of the study, the subjects to be covered and the expected timeframe, and to invite them to participate in the research. Upon acceptance, the draft report with an open-structured questionnaire was emailed to the respondents, together with an appreciation of their willingness to participate in the research. The introduction letter is attached as Appendix A. Originally it was intended to obtain written responses only, but when the Dephi approach was discarded the respondents were asked to take part in an interview as well.

Due to the qualitative and exploratory nature of this research, all input from the participants was welcomed and they were encouraged to be unrestricted and feel free to comment on all related issues. The questionnaire, which was intended to act as a guideline, is attached as Appendix B. Importantly, respondents were guaranteed that their responses would be treated confidentially and remain anonymous. The interviewee was asked for permission for notes to be taken during the interview. An outline of the questions was compiled to assist with the recording of answers. In addition to this, notes were taken during the discussion.

3.4 Data Analysis and Interpretation

One of the problems with qualitative analysis is the sheer volume of data generated, as well as the time required to process the interview notes. When time is limited a pre-structured case methodology can be used to “focus and streamline the data collection”. To achieve this, the researcher needs to establish an explicit conceptual framework, a clearly defined sampling plan, a precise set of research questions and a case outline. In an attempt to reduce this risk, the interview notes were written up in a summarised form. Further reduction was then done, as the data was reviewed

and summarised into comments. The comments were then sorted into categories. This was achieved by recording every comment in a cell in a spreadsheet, after which the cells were sorted and grouped according to similarity. These groupings gave an indication of categories and differentiations. Content analysis was conducted by comparing the categories developed with the conceptual frameworks derived from the literature review (Appendix C). Particular attention was paid to the comments that did not fit within the framework.

The role of the expert review is to evaluate the plausibility of the scenarios developed and collect views on its strategic implications. Opinions and views given by experts in related fields are added, supporting or refining the outcome of the scenario planning exercise. The key reviews, comments and thoughts from the experts were summarised. Due to the sensitive and competitive nature of the platinum-mining industry, it was expected that most of the experts in the sample would prefer to make anonymous reviews, especially the executives from the platinum mining companies. Thus, the final report keeps experts' personal information confidential and uses coded numbers instead.

The questionnaire utilised an open-ended structure to seek open, unbounded responses (Powell 2003). In the interview, participants were asked to list the key uncertainties they believed would affect the platinum-mining industry in the next ten to fifteen years. Participants were also asked to consider the potential outcomes of these key uncertainties and related forces or trends (See Appendix B: Questionnaire). The responses were then collated, and analysed for thematic content to distil a number of key uncertainties.

3.4.1 Summary of steps taken

A seven-step process was followed in analysing the data:

1. Articulation of the focal question
2. Review of past changes
3. Identification of future forces and factors

4. Identification of critical uncertainties
5. Development of the scenario framework
6. Listing of scenario characteristics and story lines
7. Summary of key characteristics

These key uncertainties were ranked based on the level of uncertainty and impact of each force and were then shown graphically.

3.4.2 Building a causal loop diagram

A causal loop diagram is a visual tool for establishing cause and effect between variables. The arrows between variables identify interactions between variables while letters “O” and “S” shows whether changing dynamics happen in the opposite or same direction between the start and end points of the arrows. A causal loop visually depicts the relationship between the entities that comprise a complex system, if one accepts the view that organisations can be characterised as control. The causal mapping technique provides its practitioners with a means of identifying and understanding the critical decision and information structures that underlie an organisation’s behaviour by visually depicting key variables and their associated feedback loops (Markoczy and Goldberg 1995).

In this research work, the data gathered on the key uncertainties was subsequently analysed to build a hypothesized model of conceptual relations. Based on the expert responses and literature, the causal loop diagram was used to identify the relationships between the uncertainties. The key uncertainties identified by the experts form the “nodes’ of the map: the relationships between forces form the causal links between nodes, to represent the interaction of forces in the environment. The relationship is represented on the graph by nodes, whilst arrows are used to represent the causal links between the nodes.

3.4.3 Constructing scenarios based on the causal loop diagram

A typical scenario methodology identifies the primary key uncertainties for the scenario space as the forces with the highest potential impact and uncertainty (Morisson and Wilson, 2997). In addition, the causal loop diagram identifies the forces that are the primary drivers. Hence the scenario stories were created around the key uncertainties with the highest impact and uncertainty, and the key drivers.

3.4.4 Evaluation of the scenarios

Several studies have indicated the criteria for the evaluation of good scenarios. The process and the completed scenarios were evaluated against the documented criteria to assess the success of the methodology in generating valuable results.

3.5 Validity and Reliability

High levels of validity and reliability are very important in research. Validity is defined as the accuracy or soundness of the research process: does it measure what the researcher set out to measure, and how accurate are the results? (Leedy and Ormond 2001).

3.5.1 External validity

In order to ensure that the research can be generalised across persons, an ideal sample would normally be a random one and be representative. External validity is the degree to which results can be generated to the population as a whole, across settings and times. This research project has two key elements, that of content (scenarios for the platinum-mining industry) and of process (of a robust scenario methodology). As the purpose of the content study is to ascertain the specific perceptions and possible futures of the platinum industry, it is not assumed that the results will be applicable in other countries or other mining industries. Scenarios are by nature specific and time-bound. Within the platinum-mining industry, however, the panel encompasses a large proportion of the total population, including major leaders. It is therefore believed that the results can be generalised in their intended

sphere. As qualitative research is conducted in the exploratory approach, the scenarios by definition and the scenario-based strategic implications are obviously not applicable to the validity discussion.

3.5.2 Internal validity

This reflects the extent to which the research instrument provides adequate coverage of the topic under study. For this study, content validity is important to ensure that the topic is fully covered. The scenario process draws out the perceptions and ensures coverage of the views of the experts in the field. Causal loop analysis also examines relationships between the key uncertainties, which will help reduce internal inconsistency. Furthermore, the feedback opportunities and post-scenario assessment assist in validation of the results and methodology.

3.5.3 Reliability

Reliability can be defined as “the consistency with which a measuring instrument yields a certain result when the entity being measured hasn’t changed’ (Leedy and Ormond 2001). Given that this study is centred on the identification of the specific perceptions and concerns of the industry at a specific time, it is highly unlikely that the same study conducted at a different time or in a different context would have the same results. Future scenarios are unique and visionary, so there is no reliability concern for scenarios and their strategic implications. Reviews on the plausibility of the scenarios and their strategic implications were supplied by a small group of experts sampled from the very limited expert population available. The reviews are exploratory in structure. Thus, the issue of reliability issue also falls away with the results of these reviews.

CHAPTER 4 PRESENTATION OF RESULTS

4.1 Introduction

Three key processes were undertaken to analyse the results. Firstly, the scenario exercise entailed identifying the key uncertainties that would impact on the results, based on the answers provided by the experts. The results obtained from the experts are shown in Appendix C. The results were then consolidated into a tabular form and subsequently distilled to the main key uncertainties which were classified according to their impact and their degree of uncertainty. The causal loop diagram was then used to identify any causation between the drivers. Finally, the scenarios are presented in a 2 by 2 matrix based on the most important drivers. A final section relates the links between the three processes, describing the four scenario stories as if they are happening in 10–15 years time.

4.2 Scenario Exercise Parameters

The development of the scenarios involved sequential consideration of the following four discrete steps:

- Identification of the forces driving change in the platinum-mining industry.
- Identification of the major uncertainties facing the platinum-mining industry.
- Choosing the two most dominant uncertainties and developing a framework for a distinctly different logic for each of four scenarios in a two-by-two matrix.
- Crafting the characteristics and logic of each scenario as they were developed.

4.3 Demographic Profile of Respondents

The demographic profiles of the respondents were close to what was planned. However, a number of executives were not available for several reasons, in particular the fact that they were preoccupied with managing their companies during the economic crisis. Nevertheless, the results obtained are well spread and represented a good sample for analysis.

4.4 Summary of Relevant Key Driving Forces

Tables in the next pages show the summarised key driving forces identified in the course of discussions with the various respondents. These forces are relevant to the research question presented.

4.5 Analysis of Key Driving Forces

The major driving forces of change are shown in Figure 7 below grouped according to two elements: (i) level of uncertainty (ii) and the nature of the impact that these drivers would have on the platinum mining environment. The main drivers that had a high uncertainty and the highest impact formed the key uncertainties. It is shown that most factors with a large impact are predetermined. There are, however, other factors with a high potential impact which are also highly uncertain and these formed the basis of the scenarios constructed.

CLASSIFICATION (PESTELE)	KEY DRIVING FORCE	POSSIBLE IMPACT	POSSIBLE OUTCOME
Rapid Alternative technology changes (Technology)	Wide adoption of alternative energy technologies. (greener new technologies)	As oil prices and cost of polluting keeps increasing, alternatives will become increasingly attractive. Alternate energy sources for transportation (batteries, etc.). The path to zero emissions prompts adoption of new technologies that do not require PGM hence could displace PGM demand	PGM based fuel cell adoption increase hence increased platinum demand. On the other hand reduced demand, with newer technologies not requiring any pgm, making metal obsolete in time, unless new applications are investigated.
	Successful application of low-level PGM applications in auto catalysts. (Thrifting)	Several Japanese carmakers have released new models with significantly lower PGM load, applying nanotechnology to allow for thrifting.	lifetime of the car, this trend will surely gain further ground. This would erode PGM demand in its biggest application area. Other automotive research aiming to reduce PGM cost in catalysts, by changing the metals used and reducing their specific consumption
	Fuel Cell Technology Uptake	Fuel cell technology will take over replacing all gasoline and diesel vehicles. This will be the future for greener technology. New technologies driven by legislation . Increasing use of fuel cell technology particularly stationary fuel cells as a clean energy source – use supported by continued R&D and possibly legislation in developed countries	PGM demand may exceed supply and securities around the ability of platinum companies to meet demand may necessitate adoption f other non-Pt based technology. Increased demand for Pt for use in fuel cells becoming significant in 15 years
	Technology change	Adoption of platinum based electric fuel cells as zero-emissions technology of the future. However competing technologies could displace PGM demand in the automotive segment. Hybrids, plug-in hybrids, Hydrogen internal combustion, battery electric and fuel cell electric could all change the PGM industry structure.	Possible downward or upward pressure on PGM demand due to limited scope for tightening of emission standards and smaller vehicles
	Alternative transportation modes / automotive technology (alternative to catalytic converter)	If the demand for Pt in the transport industry were drastically reduced, it would significantly negatively affect demand	Linked to consumer preference and policy positions, significantly influenced by global concerns around Climate Change
	Application of PGMs	Consumption is driven by volume and by the pervasiveness of the use of PGMs. PGM core application is as a catalyst owing to the Group specific chemical properties. Development of new techniques may reduce consumption (increase efficiency of use) but the key threat would be substitution by another material that can achieve similar catalytic efficacy.	Reduced necessity for PGMS (ie substitution) will result in reduced consumption in certain applications
	Energy concerns	Shift in use of fuel as fuel price increase drives for alternative electric cars etc	Substitution of pt based autocatalysts
	Increasing adoption of electric and hybrid vehicles	Increased government funding (developed countries) into green technologies including lithium ion batteries and the resulting increased commercial viability of lithium ion batteries in the powering of motor vehicles will result in a greater percentage of sales of hybrid and electric vehicles	Hybrid vehicles continue to gain market share (PGM demand neutral) however electric vehicles begin to make a noticeable impact on sales of diesel and petrol powered vehicles in the next 15 years and reduce demand for PGMs
Emission Legislation (Legislation)	Legislation on emission control: Drive for cleaner energy	Due to increase in global warming, there will be an increase in even stricter legislation around emission control. This will be driven primarily by global warming necessitating the need for more efficiency in energy use.	PGM demand may or may not increase depending on the technological front of greener cars. Other automotive research aiming to reduce PGM cost in catalysts, by changing the metals used and reducing their specific consumption. Changing societal values and increased environmental pressures. New rules of game, energy diversification based on cleaner greener energy sources. Carbon footprint becomes the norm on a daily basis
	Legislation-driven catalytic control of automotive and non-road engine emissions	Global legislation continues to develop regarding acceptable levels of engine pollution. Automotive catalyst demand will be driven largely by increased number of vehicles globally, whilst non-road catalyst demand will be produced by new waves of legislation	Increased use of pgm, notably platinum, palladium, and rhodium. Engine technologies will develop offering higher efficiency/less pollution per unit distance travelled, but all currently conceivable major technology developments for the 10 – 15 year horizon will require pgm catalysts in one form or another

CLASSIFICATION (PESTELE)	KEY DRIVING FORCE	POSSIBLE IMPACT	POSSIBLE OUTCOME
Global Economic Performance (Economic)	Prolonged Recession/Double Dip Recession	Pt supply outstrips demand. Current recession continues in waves for next half-decade, exacerbated by instability in the east and protectionist policies in the major world economies – affects global markets for next decade. Another global recession impacts on the demand for autocatalysts and shifts demand dynamics.	The effects are not necessarily just constriction – possibly new geo-political formations, economic logic, etc. Downward pressure on demand growth and may result in prolonged mine closures. Shifting industry demand dynamics e.g increased demand in investment sector and jewellery, economic and financial pressures
	Chinese and Indian growth	Insatiable demand of PGMs resulting in demand outstripping supply hence concerns of security of supply	Substitution for either non-Pt based items or other PGMs eg. Pd in autocatalysts
	Increased middle-income population	Middle-income consumers purchase motor cars	As middle-income numbers expand significantly, the demand for vehicles could grow exponentially (and therefore also the demand for fuel cells).
	Global economic growth / macro economic forces	The rate of growth of the global economy and the respective points of growth – developed or emerging economies drives PGM demand. The three major sectors of PGM consumption are auto catalysis, industrial applications and jewellery. These are directly linked o economic activity – national level for the first two and personal for jewellery	A decline in economic activity in the countries concerned with or adhering to the "euro emissions" protocols results in a decline in PGM consumption. A drop in disposable income results in a drop in jewellery sales. Movements in the macro economy affect demand = direct casual link. This casual link is moderated / increased by shifts in the core application of PGMs for catalysis eg increased efficiency of use (reduced autocat loadings) reduces unit consumption. Conversely the development of new applications for PGMS eg Ru in memory drives and Pd for inhibiting fruit ripening increases consumption
	Consumer confidence in developed markets	Consumer confidence is key in determining purchase decisions of consumer durables like motor cars, which are the single biggest demand driver for PGMs.	A prolonged Western recession would suppress consumer confidence and delay car purchase decisions as long as possible, or lead to buying smaller cars, perhaps leading to reversal of market share growth of hybrid cars (US) and diesel powered cars (EU) and hence a reduction of PGM usage per car and a shift from Pt (diesel) to Pd (petrol). Access to finance for consumers, as that would also impact on their ability to buy a new motor car.
Industry Economic performance	Access to capital	Many juniors are facing extremely difficult conditions with accessing financing to allow these companies to continue with their project development. This is particularly true for early stage projects and less attractive ones.	More than half of all junior mining companies are likely to disappear as going concerns due to running out of cash. Some of the underlying resources will trade hands and may be developed further under new ownership. This trend will reduce the potential for the industry to grow long-term supply and thus meet future needs when PGM growth in developing markets picks up and Western markets rebound.
	Mining cost inflation	The lack of workers available to meet the need for growing pgm supply in an ever more complex mining environment (eg greater depth) will lead to mining cost inflation well ahead of CPI growth. This in turn will damage productivity which will drive unit costs still higher. Continued high demand (and constrained supply) for tyres, explosives, fuel, timber, machinery, etc are contributing to high opex escalations	Rationalisation of mine industry structure, with disappearance of higher cost producers. Pgm price base, although subject to volatility due to market sentiment, will become cost rather than market driven. Increasing operating costs
	ZAR strength/volatility	While end-use demand is denominated in US$, South African supply is denominated in ZAR (due to the cost base)	Rising cost pressures could yield SA PGM production as uncompetitive and force prices higher and reduce end-use demand through driving substitution – a weaker ZAR reduces the required US$ metal prices needed for companies to break-even and generate returns allowing for greater production and end-use demand.
	Industry Economic performan	Economic conditions under which the industry will operate in the future.	Industry could experience extended periods of strong prices, growth and productivity supporting the economic viability of new mines and enhanced access to capital.
	Downstream processing and re	Downstream processing is a barrier - requirement for smelter capacity of X for a viable investment). Currently there is no major independent smelting and refining capability – new entrants will largely depend on current incumbents' capacity.	The multitude of juniors and intermediate Pt miners could provide an opportunity for an independent processing facility. Alternatively, through backward integration, customers could provide a facility to ensure constancy of supply.

CLASSIFICATION (PESTELE)	KEY DRIVING FORCE	POSSIBLE IMPACT	POSSIBLE OUTCOME
Industry Economic performance	Industry projects risk	Although not specific to the PGM Industry a number of factors have meant that the complexity and risk involved in carrying out mining operations and executing mining projects in Southern Africa has increased.	Reduced production from current operations, project suspensions and delays, increased project hurdle rates to account for increased risk, increased infrastructure and project feasibility costs
	Industry Profitability	Shallow, low cost, good grade ounces are progressively being depleted and replaced by deep, high cost ounces. Replacement ounces require significant capital investment to sink deep shafts and develop related infrastructure. Difficult ground conditions and lower grades result in reduced production and increasing costs on a cost per ounce basis. South African mining houses are having to mine deeper for lower grade ore, increasing the cost structure of the industry	Result is closure of unprofitable shafts and reduced production and the deferment of capital to develop shafts to produce replacement ounces resulting in a decrease in supply. Rising cost pressures could yield SA PGM production as uncompetitive and force prices higher and reduce end-use demand through driving substitution.
Ore quality degradation	Ore quality degradation	The PGM majors are progressively mining more UG2 as opposed to Merensky ore. Merensky ore with high nickel and copper content is required for the safe and optimal operation of the furnaces operated by the majors. In addition, mines are getting deeper, geology complex, grade lower and constraints upstream impacts on profitability of industry. This will increase operating costs.	Focus on newer technology – use of DC furnaces – and focus on PGM projects (or even nickel and copper sulphide deposits) rich in nickel and copper. Supply constraints hence driving alternative technology and thrifting.
Shifting Industry trends (Social)	Increased efficiency of recycling of PGM's	Currently not all PGM's that are produced are recycled. There is a net 'consumption' on an annual basis resulting from inefficient recycling processes, manufacturing techniques, legislation and social drivers. Industrial recycling is largely efficient with the majority of material re-entering the recycle stream, Auto catalyst recycling efficiency is a function of point of use of vehicles, legislation, recycling facilities and social pressure. High recycle occurs in Europe, N America, Japan but is virtually non existent in Africa, most S America and most of Asia! Legislation in EU requiring recycling of vehicles and increase in recycling of vehicles in USA will result in substantial increases in supply of Pt, Pd and Rh from secondary sources.	Increased recycling – collection and recovery provides a lower cost, more "cycle robust" source of metal for major consumers. Major consumers integrate recycling into their business models and reduce demand for new metal to net market growth. Consequently, an increase in secondary supply dominated particularly in China and India as new emission legislation comes into floods the market impacting on new mine supply . In 10 to 15 years secondary supply could account for more than a quarter of all Pt, Pd and Rh supplied.
Shifting Government Policies (Political)	Resource nationalisation	Driven, particularly in less democratic and newly formed states (including African, former Soviet, and Asian states. Calls for nationalisation could affect the feasibility and attractiveness of mining platinum. The drive of emerging economies to get access to resources through foreign direct investment and share ownership as is being pursued by China, India and more recently Russia.	Limited expansion of private mining, Constriction of industry. Nationalisation is rejected, but not without some degree of acrimony. Foreign governments funding access to resources.
Changing societal values (Social)	Power shift to society and geopolitically	The dominant power moves away from government and big business as has traditionally been the case to society. The "West" no longer yield the world universal power as new power blocks have emerged: BRICA –Brazil, Russia, India, China and India	Society demands better practices and standards in business; sources of capital are now wider which allows new business models to emerge. the demand and supply situation for PGM's remain high but with society demanding more on how they are mined and marketed..
Investment demand (ETFs) (Economic)	Investor community interest covers a broader range of commodities, including pgm	A probable fall-out from the global banking sector and economic crisis is investment in a broader range of commodities beyond gold, bonds, and company equities. Platinum and palladium are likely to attract such interest with a wider audience and in different product forms from those currently seen. ETF demand for Pt and Pd increase and destabilise supply and demand dynamics resulting in price volatility.	Large investments and disinvestments which will lead to price volatility and increasingly make price more dependent on market sentiment than on supply/demand fundamentals. Price volatility and un sustained demand of PGMs.
Substitution (Economic)	Cannibalisation of Platinum with Palladium	High Pt prices drive substitution of Pt with Pd. Additionally, significant new strides made in thrifting will reduce PGM loading on Catalytic converters. Or increased in Pt substitution by other pgms or non-Pt based.	Reduced demand hence downward pressure on Pt price. Price increase of Pd
Industry Restructuring: Consolidation/New business Models (Economic)	New consolidated Entrant	Consolidation of juniors or creation of equally sized large corporations, without an outright industry leader.. This threat could be exacerbated if this were coupled with the financial resources of an existing major. Consolidation of the PGM industry in the creation of equally sized large corporations, without an outright industry leader. Government policy has favoured/promoted new entrants, through empowerment partnering for new order rights.	Shift in industry structure and possible new business models

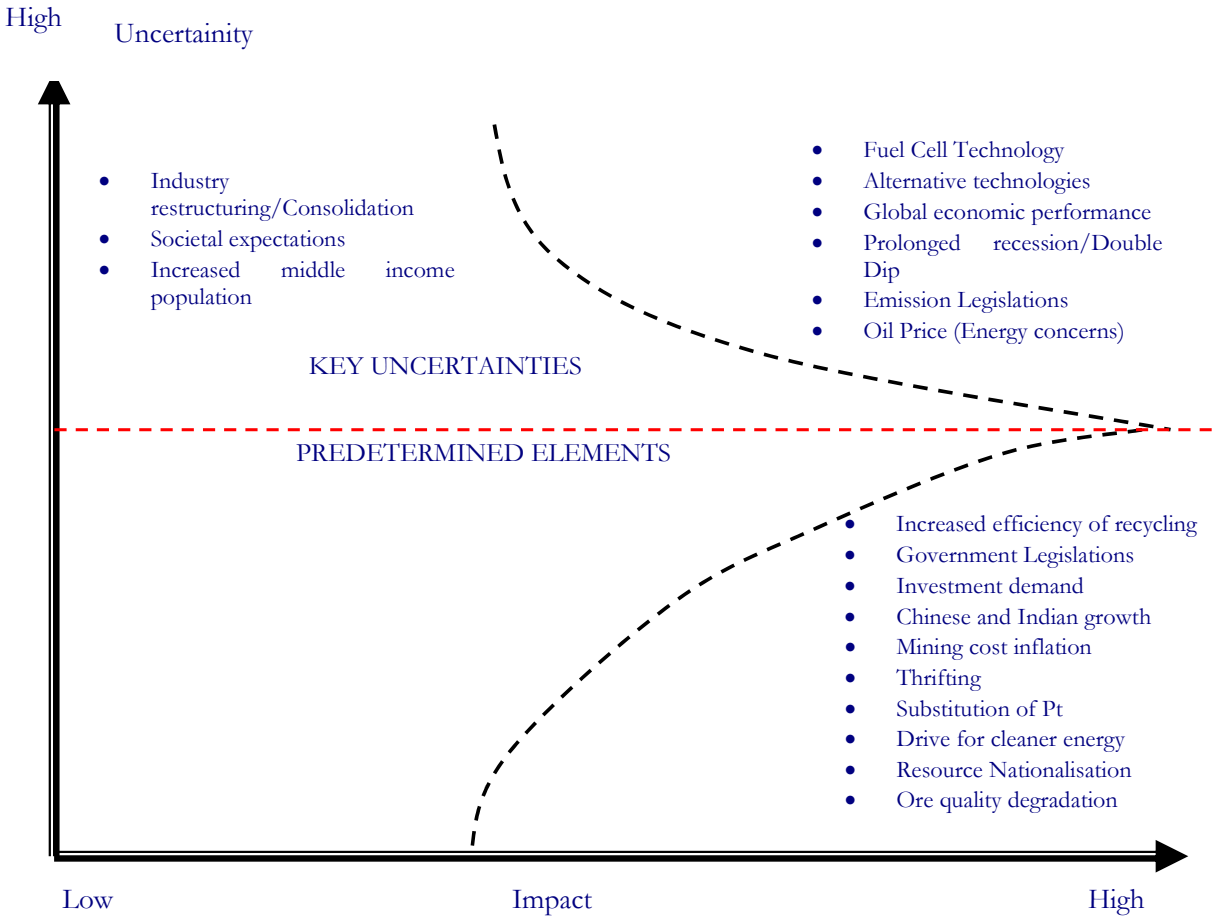


Figure 7: Key driving forces grouped according to level of uncertainty and impact

4.5.1 Causal loop analysis: Identification of the major uncertainties

The next step focused on the identification of the two main key uncertainties facing the industry. These are the key driving forces the future outcomes or impact of which are uncertain, particularly important in scenario thinking because they define the range of possible futures. They lead to the divergence in the future. The two critical uncertainties that dominated all others were identified through the causal loop model, as shown in Figure 8. These were classified based on the PESTEL (Political, Economic, Social, Technological, Environmental and Legal) theme.

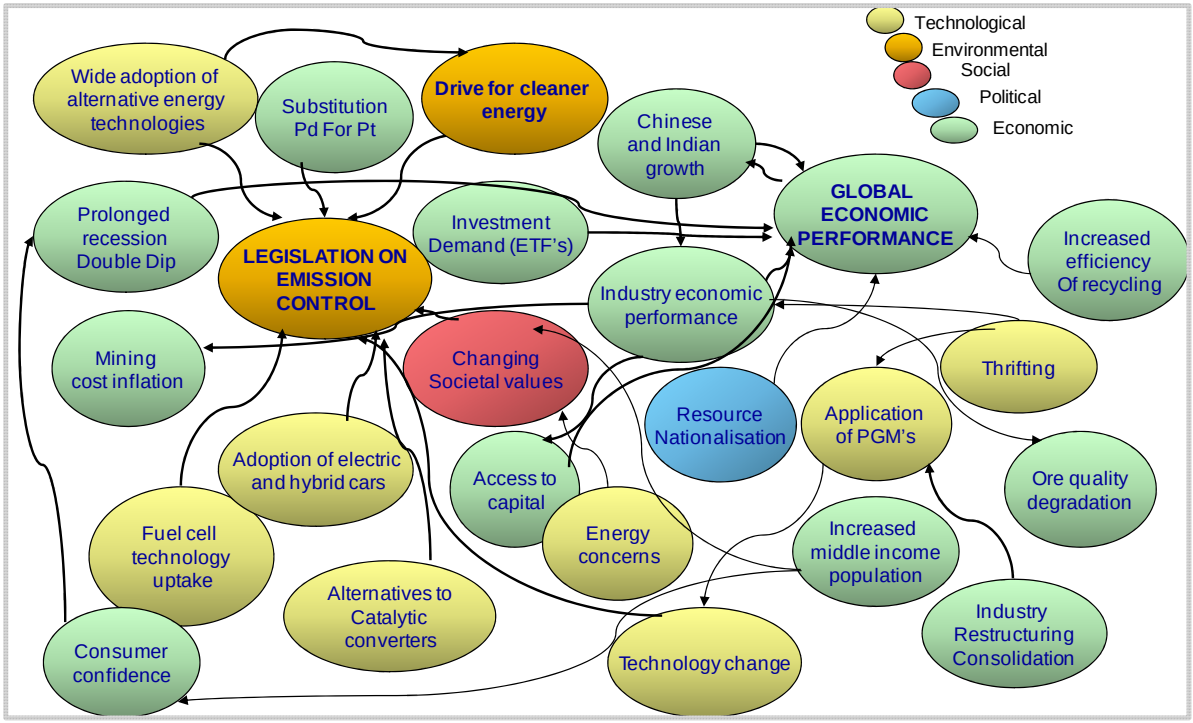


Figure 8: Causal loop diagram of the key driving forces for the platinum industry

Causal loops are representations of individual or group beliefs about causal relations. They include elements with only two kinds of properties. The first property is “relevance”. The second is the possibility of being one (of two) influence relationships (positive or negative). The causal loop method was ideal in this study as it identified the main driving force and automatically indicated the rank of the variables. The main driving force is shown by the highest number of arrows pointing towards it. In this instance, the two main driving forces have been identified as:

- **Legislation on Emissions Control,** and
- **Global Economic Performance**.

These are the two most critical drivers (based on the criteria of them being both the most critical uncertainties as well as the most impactful on the focal question). Scenarios were subsequently constructed around these two key driving forces.

4.5.2 Legislation on emissions control

An increase in even stricter legislation around emissions control is forecast by many. This will be driven primarily by global warming necessitating the need for more efficiency in energy use. Global legislation continues to develop regarding acceptable levels of engine pollution. Automotive catalyst demand will be driven largely by increased number of vehicles globally, whilst non-road catalyst demand will be produced by new waves of legislation hence the increased use of PGMs. Engine technologies will develop offering higher efficiency and less pollution per unit distance travelled, but all currently conceivable major technology developments for the 10–15 year horizon will require either PGM based or non PGM based catalysts in one form or another. Increased government funding (in developed countries) into green technologies including lithium ion batteries, and the resulting increased commercial viability of these batteries in the powering of motor vehicles may result in a greater percentage of sales of hybrid and electric vehicles.

4.5.3 Global economic performance

This driver relates to the performance of the global economy. It has been identified as a key driver for the platinum industry, which is not surprising given the significant impact of the recession on this industry in 2008. Under what economic conditions will the industry operate in the future? On one hand, the industry could experience extended periods of strong prices, growth and productivity supporting the economic viability of new mines and enhanced access to capital. On the other hand, the industry could experience extended periods of downturn with weak prices, low growth and limited productivity improvements.

One of the greatest challenges for the platinum-mining industry is to ensure that its business model is sustainable across all potential future cycles of global economic performance, thus ensuring the ability to weather ups and downs, and sustain profitability throughout. There are strong assumptions that the global economy is close to recovery and will soon be growing due to Asian growth primarily led by China and India. If these assumptions were to be tested, as was previously seen with the recent global economic crisis, a completely different picture would emerge

in which some of the scenarios could have devastating effects for the platinum-mining industry. There are several factors that could trigger another global economic crisis, such as dominance by China and India, impact of the US on the global economy and factors such as those that contributed to the present crisis – for example, the widespread granting of sub-prime mortgages.

4.6 Scenario Construction

The above two key uncertainties provide a logical framework for developing distinctly different scenarios and may be represented as continuums or dimensions shown as orthogonal axes (see Figure 9). The key drivers were mapped on a 2 x 2 scenario matrix with four quadrants, each depicting a scenario (Vant, Klooster and van Asselt 2006). The scenarios were given names to symbolize what is happening in the scenario. Each quadrant represents a unique combination of outcomes of the two critical uncertainties. The following questions are posed for each quadrant:

- How does this future come about?
- What developments need to occur for this future state to emerge?
- What are the major characteristics that would describe this scenario?

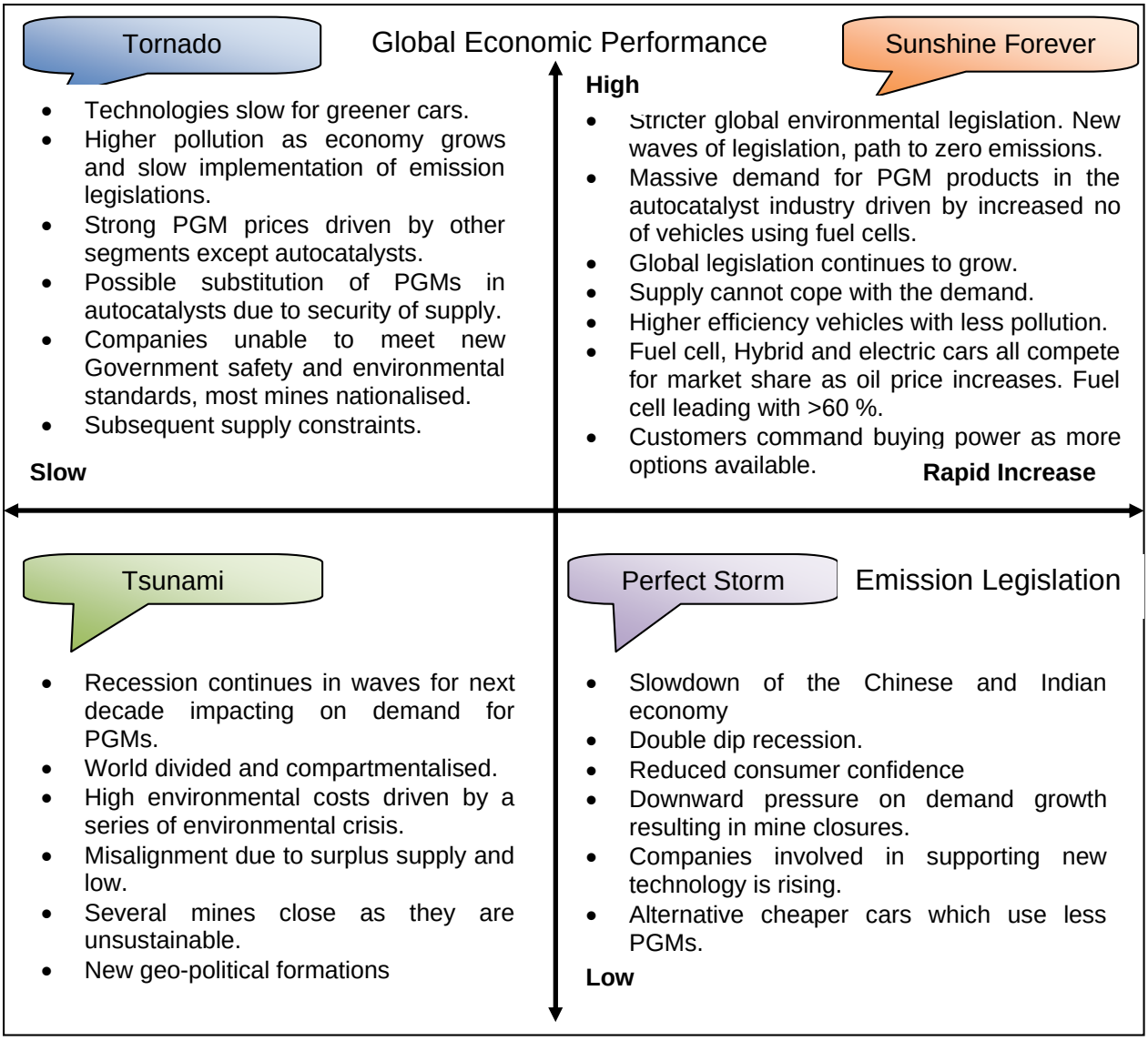


Figure 9:Proposed platinum-mining industry scenarios

4.7 Description of the Scenarios

4.7.1 Sunshine Forever: High Global Economic Performance and Rapid Increase in Emission Legislation

"Sunshine forever" is a world characterised by a coincidence of strong economic conditions and high demand for PGMs driven by the rapid increase in emissions legislation. Economic growth and improved margins lead to improved cash flow and access to capital across the industry from majors to juniors. The potential for viable

business opportunities leads to the emergence of new mining and mineral companies. Technology and productivity improvements are critical in lowering costs, more effectively managing wastes and improving margins. Stock markets reward triple bottom line companies. Simultaneously, a healthy economic environment is envisioned, reflected by strong commodity prices, robust growth and productivity improvement in the mining and minerals industry. It is an optimistic future. The demand for “green products” increases and leads to an accepted system of “certification for sustainability”. A restructuring of the industry and its value chain occurs built around the full metal/mineral life-cycle; major programmes lead to enhanced recycling and overall energy efficiencies.

This scenario is partly a result of China and India exceeding all growth expectations. Major technological breakthroughs have led to the successful penetration of fuel cell technology and the rapid growth in demand for PGMs associated with a green technology. This, together with a demand for jewellery, demand within certain niche markets and ongoing steady demand for autocatalysts make supply capacity the challenge. Given this supply challenge, this scenario is characterized by mergers and acquisitions as well as the emergence of significant new players. In addition, competition for resources intensifies mainly from China.

The global economy recovers with renewed and sustained growth. There is a strong demand for PGMs with high prices. Increased cash flow for companies supports investment. Alternative energy technologies like fuel cells have accelerated, leading to significant demand for PGMs. Many PGM mining sites previously considered sub-economic are now re-assessed and found feasible. Mines have become mechanised with improved productivities and efficiencies. Across the industry, this combination of stronger prices associated with the global economic performance and the lower operating costs result in much improved margins and return on investment. Subsequent Pt price reaches all high levels. This is all contributed by the investment demand of the PGMs. Investors buy ETFs heavily as the prices rise hence adding to the upward pressure on the price.

Safety-related death is a thing of the past with improved technologies which reduces human exposure underground. Stakeholders’ engagement in planning and

decision-making to raise environmental performance improves. They understand the need to promote best practices in operations, expand stakeholder engagement and embrace sustainable development principles in practical ways. Consumer expectations in terms of demands for “green” and “socially responsible” products increase significantly. Consequently, there is competition for market share between fuel cell cars, hybrids and electrical but overall demand of PGMs remains very high as fuel cell technology leads the way. Certification that the metals/minerals have been produced from mines operating according to the new sustainability standards, or have been recovered through recycling, gains momentum and becomes firmly established. Auto companies are designing cars from a life-cycle perspective – with recycling of PGMs. The role of recycling in the value chain intensifies, in particular autocatalysts. Some mining companies become more integrated, with this activity forming a key part of their business model. Recycling economics improve over the course of the decade. Premiums are paid for certified “green” products.

Fuel cell technology may take over, replacing all gasoline and diesel vehicles. This will be the future for greener technology. New technologies are driven by legislation. There is increasing use of fuel cell technology, particularly stationary fuel cells, as a clean energy source – a use supported by continued R&D and possibly legislation in developed countries.

4.7.2 Tornado: High global economic performance coupled with slow emissions legislation

In this scenario, all is not well. Tornadoes are funnel-shaped storms which rotate much like tsunamis; but are much smaller, hence the name “Tornado”. Economic growth raises prices and creates financial prosperity for the industry. Share prices rise and mergers and acquisitions reflect rising cash flows. There is renewed investment in exploration, R&D and automation technology whilst labour demands increase. This world is too good to be true but all is not that well. While the economy and economic wealth are growing, emissions control get on the way as companies are not forceful in energy and water efficiencies. Productivity reduces and safety

stoppages are frequent; because companies can't meet government requirements and most mines end up being nationalised.

Tornadoes are violent because of their speed and the unpredictable behaviour. In this scenario the increased economic growth rates, especially emerging from China and India, creates an insatiable demand for energy driving the search for reliable and cheap energy sources. This results in renewable energy sources and technologies increasing. These technologies unfortunately are not platinum based, reducing the significant need for PGMs in autocatalysts. The new disruptive technologies are quickly used and are very cheap, and their emergence has rocked the long-flourishing PGM industry. Therefore, it appears the increased cost of platinum has driven for its substitution. As a result, there are developments of new applications for PGMs but its use is limited.

PGM prices plummet due to supply surplus while jewellery demand initially increases due to high levels of disposable income associated with high growth combined with the falling PGM prices. The result is a very unprofitable and diminishing platinum industry. On the other hand, reduced demand, with newer technologies not requiring any PGMs, makes the metal obsolete over time, unless new applications are investigated. For the auto industry still using the PGMs, this world is characterised by a reduction in PGM cost in catalysts, as consumption is reduced. There may be a possible downward or upward pressure on PGM demand due to limited scope for the tightening of emission standards. This is also linked to consumer preference and policy positions, significantly influenced by global concerns.

4.7.3 Tsunami: Low global economic performance coupled with slow emissions legislation

In this scenario, depressed economic conditions spiral downwards, hence the name "Tsunami", which is like a huge wheel of thunderstorms dangerous because of their size and speed. The possibility of reversing the trend seems remote. This scenario is characterised by low margins and cash flow, low share prices, minimal investor interest, restricted access to capital, cost cutting, deferral of maintenance

expenditures, and temporary mine closures. Interest in mining as a career diminishes; mining schools shift their focus to related fields to survive. Venture capital funds dry up and exploration activity almost entirely disappears. This indeed is a Tsunami scenario. A prolonged recession may suppress consumer confidence and delay car purchase decisions, or lead to increased purchases of smaller cars, and possibly a reversal of the market share growth of hybrid cars (US) and diesel powered cars (EU) and hence a reduction of PGM usage per car and a shift from Pt (diesel) to Pd (petrol). Limited access to finance for consumers also impacts on their ability to buy a new motor car.

Platinum mining struggles as low commodity prices from oversupply persist in a similar manner to the events of 2008 but to a greater degree. Low economic growth creates insufficient demand for PGMs. Investor interest in Pt mining shares continues to diminish and Pt mining share values remain depressed. Since purchases and sales of ETF shares have been highly correlated to movements in the metal price, particularly for platinum, investors are selling heavily as the PGM prices collapse exacerbating the fall in the platinum price by adding liquidity to the market. Investment firms lay off the the majority of their mining analysts and bankruptcies increase with almost few technological advances. Mining practices degrade, since short-term cost reduction initiatives take precedence over long-term planning. A large portion of stay-in-business costs are deferred in an attempt to preserve cash. High grading of ore bodies provides a short-term approach to maintaining operations but severely compromises the long-term efficient exploitation of the ore body. There is further consolidation in the industry on a global scale. Only a small number of companies recognize the need for revamped business models that include an interest in autocatalyst recycling.

This scenario is also driven by mayhem in the global environment, resulting in irresponsible industrial development. Economic considerations have superseded sustainability obligations, and global warming has resulted in the start of a series of environmental crisis. The environment is characterised by high pollution levels and shortages of natural resources such as water and oil. There is increased frequency of natural disasters hence damaging infrastructure and farm land. The call for

nationalisation by certain South African government officials 15 years ago becomes a reality. This not only takes place in South Africa but across the globe. There are tense relations between the platinum mining industry, the communities, and the state, resulting in a generally unstable and unpredictable environment. This has resulted in a deterioration of world resource markets. The platinum industry is a high cost environment as a consequence of the environmental crisis, the high cost of ensuring security of supply of raw materials (including energy) and safety challenges concerned with deep level mining. The slump in the global economy increased by both a general negligence of the environment and the availability of cheaper substitutes in its industrial applications has resulted in reduced demand for platinum. This, together with spiralling operating costs, results in the closure of platinum mines. The impact of mine closures devastates some mining communities. This causes problems for governments both in supporting these communities suffering job losses and in dealing with abandoned mines. There is increased social unrest by communities as a result.

There is limited economic viability of new mines as Pt supply outstrips demand. The current recession continues in waves for the next decade, exacerbated by instability in the east, and protectionist policies in the major world economies affect global markets. This world is catastrophic in nature.

4.7.4 Perfect Storm: Low global economic performance and increased emissions legislation

In the perfect storm, difficult economic conditions serve to drive innovation. The overall result is that difficult times give way to more encouraging conditions, like a storm with a good result. Another global recession impacts on the demand for autocatalysts and shifts demand dynamics. Chinese and Indian growth may trigger insatiable demand for PGMs, resulting in demand outstripping supply hence concerns of security of supply. The reduced rate of growth of the global economy and the respective points of growth drives reduced PGM demand. However, The main driving force is that industry is moving towards sustainable development.

Economic and financial conditions exert significant pressures on industry and government. The above driving forces lead to the following changes:

- New industry values, with more focus on sustainability.
- Behaviour change driven by enhanced environmental awareness.
- Industry restructuring through consolidation and rationalisation.
- Innovation and new business models.
- Performance change – new standards of performance.
- New social and environmental best practices and operational responsibilities.
- New coalitions and support for a transformed industry.

In this scenario, economic and social pressures initially push the Pt mining industry to the limits of survival. Low demand undermines economic growth and real prices decline for the PGMs. At the same time public environmental and social concerns remain high and non-government organisations are influential in raising their concerns. The path to zero emissions prompts the adoption of new technologies that do not require PGMs, which threaten the PGM demand. But platinum-based electric fuel cells are also adopted as the zero-emissions technology of the future and the demand for these is much higher. These competing technologies fight for for market share in the automotive segment. Hybrids, plug-in hybrids, hydrogen internal combustion, battery electric cars and fuel cell electric cars have changed the structure of the PGM industry. As oil prices and the cost of polluting keep increasing, alternatives have become increasingly attractive.

Environmental problems – globally and nationally – further erode the mining industry's image and credibility. Declining earnings for most companies and losses for some lead to declines in share prices. These pressures trigger a series of mergers and acquisitions. This consolidation contributes to rationalisation of mines. In many cases, implementation of closing mines is deferred in the hopes of better financial conditions to come. The overall dynamic creates an atmosphere of uncertainty but new investment in technological or intellectual capital continues.

Depressed global prices don’t last forever and rising prices and margins due to a renewed market demand in the green technologies creates increased financial scope to expand the opportunities for companies to act. Despite a slowdown in world economic growth, stricter environmental legislation uplifts the platinum industry. The platinum industry is still in an enviable position due to its proactive R&D, due to the stricter environmental legislation and development of alternative fuel technologies. The profitability at the PGM industry for fuel cell components and engine-based industries sustains its growth in demand in the industry. These new global environmental concerns have created new sources of opportunities and increasing demand for platinum. From an investment perspective, demand for ETFs in this world starts to increase as the PGM prices start to rise due to renewed demand in the technologically sector. This can have the impact of reducing liquidity in the market and of increasing price volatility. Although the world is decreasing its dependence on internal combustion engines, the wide pursuit of clean energy (due to the increasing oil price and environmental pressure) has led to the adoption of platinum-based fuel cell technology. This indeed is a perfect storm for the platinum mining industry

CHAPTER 5 DISCUSSION OF THE RESULTS

5.1 Introduction

The study has revealed that the two key driving forces that will impact on the platinum-mining industry over the next 10 to 15 years are Global Economic Performance and Emissions Legislation. These key drivers have the highest uncertainty and will have the highest impact on the platinum industry.

5.2 Discussion: Platinum Industry Scenarios

In the literature review two research questions were proposed.

- What are the key uncertainties of the platinum-mining industry which will impact on the industry in the next 10-15 years?
- What are the future plausible scenarios for the platinum-mining industry in the next 10-15 years and the implications?

This study has identified the key uncertainties of the platinum-mining industry which will impact on the industry and this is the first time that these key drivers have been identified together. It is interesting to note that a similar driver to Global Economic Performance was previously identified by other authors (Smith et al. 2009). In their study, the authors defined the concept of a linkage between long-term planning parameters (‘global assumptions’) and possible future world views as conceived in scenario planning. The main drivers identified in this study were supply and demand of PGMs and the scenarios were linked to the assumptions used for long-term mining planning. In addition, Genc (2008), concluded that the future of the platinum price will depend heavily on the supply and demand patterns. This study therefore confirms that the main driver is the Global Economic Performance and supply and demand are essentially driven by that. On the one hand, a study on the future shifts in PGM demand in 2016, Watts et al (2008) concluded that demand for the PGMs will remain strong driven by legislative requirements to improve fuel efficiency,

implying the key driver for the future of platinum is the emission legislation. This study by Watts et al (2008) therefore is consistent with the findings in this study that Emissions Legislation is one of the key driving forces for future of the platinum – mining industry.

The literature review highlighted some of the forces that could shape the future of the platinum industry and these were confirmed by the outcome of the experts' views in this study (Yang 2009; Watts et al. 2008). For example, the adoption of hybrid cars and fuel cell technology uptake were commonly identified. There is evidence that these some of these technologies are already available and many car manufacturers are working on making these cars commercially available (Yang, 2009).

It may appear as though there is some certainty that these technologies will shape the platinum industry in the future. However, the uncertainty lies with the timing and the extent to which they will have an impact on the platinum industry. In an article by Bower and Christensen (1994), the authors state that one of the most consistent patterns in business is the failure of leading companies to stay at the top of their industries when technologies or markets change. The pattern of failure has been striking especially in the computer industry. The key issue in this scenario analysis is that it highlights the fact that platinum mining companies may fail to make certain technological investments that customers of the future may demand. Such an example is the fuel cell technology. What should the platinum mining companies be doing in order for the industry to maintain dominance in the auto car industry should further legislation favour more greener cars? Below is a diagram that shows how foresight should be used for strategic decision making:

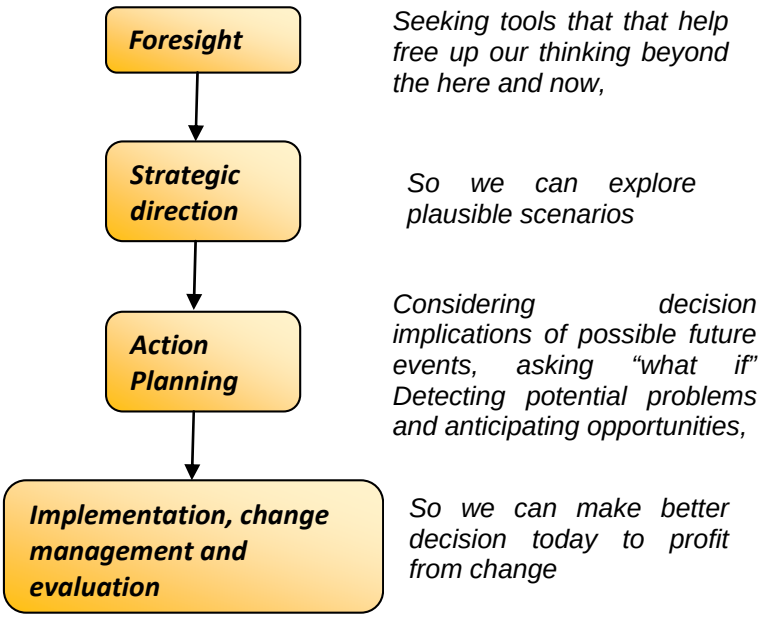


Figure 10: Using foresight for strategic decision making (Gordon 2008)

In evaluating the scenarios developed, it is noted that the scenarios generated in this study pass the criteria. Table 4 shows the various sources of literature on different criteria for evaluating scenarios developed by the author (Kipps 2007). The scenarios generated seem to pass the various criteria proposed for evaluating scenarios. The most important is that they are plausible and will therefore trigger more questions for the executives of the platinum-mining industry. To avoid strategic surprises (the sudden realisation that one has been operating on the basis of an erroneous threat perception (Fahey 2003) organisations need to anticipate, understand, and develop strategies for coping with the impact of external environmental forces on an organisation.

Table 3: Criteria for evaluation of scenarios (Kipps 2007)

CRITERIA	SOURCES	EVALUATION OF SCENARIOS
Internal consistency/Coherence:	Futures Group, 1994; Schoemaker 1995; Ratcliffe 2000; Godet and du Roubelat, 2003: Glenn and Gordon, 2004	Scenarios created are consistent amongst themselves. The uncertainity outcomes are mutually exclusive. Achieved through use of Causal Loop Analysis
-Trends compatible within timeframe		
-No mutually exclusive combinations		
-Also consistency among scenarios		
Plausibility/Likelihood	Futures Group, 1994; Schoemaker 1995; Ratcliffe 2000; Godet and du Roubelat, 2003: Glenn and Gordon, 2004	Scenarios created are plausible as they are challenging and the trends can be seen in the present day, e.g. the credit crises
-Internal consistency		
-Causal connections with present		
Relevance	Wark and Duncan, 1994; Futures Group, 1994; Schoemaker, 1995; Ratcliff, 2000; van der Heijden, 2000; Glen and Gordon, 2004	They pass this test as they are very relevant to the platinum industry. They focus to the critical needs and issues facing the industry. These will be useful in decion making and planning for these organisations
-Usefulness in decision making and planning		
-Focussed on critical need/issues facing the organisation		
-Enable proactive decision-making, early indicator scanning		
Challenging	van der Heijden, 2004; Glenn and Gordon, 2004	The scenarios generated will definitely challenge industry assumptions, e.g. The surprise that may come with much higher demand for electrical cars and than fuel cells
-Unique implications for strategic decision making and planning		
-Ability to illuminate different futures		
Archetypal	Schoemaker, 1995; van der Heijden, 2004	The scenarios generated will have an ability to be memorable. They are compelling and vivid and readers will be able to viusualise such a world.
-Compelling		
-Describe generiocally different futrures, not variations		
-Simplicity and evocativeness (including in name)		
Stability	Schoemaker, 1995	The scenarios have described an equilibrium rather than a transient state.
-Describe an equilibrium, not a highly transient state		
-Major stakeholders are in reasonable positions		
Credibility	Schoemaker, 1995; Godet and du Roubelat, 2003	The methodology used ensured active participation of the experts. However, the method could be improved by having a workshop to reach a consesus on the key driving forces
-High degree of ownership of finished product		
-Transparancy of process to users		
Comprehensiveness	Godet and du Roubelat, 2003	Scenarios generated span a reasonable extent of the range of probable platinum futures hence passes this test
-Scenarisos span a reasonable extent of the range of probable futures		

5.3 Conclusion

From the interviews conducted there are indications that the Global Economic Performance and Emissions Legislation are the key drivers that will have the highest impact on the platinum industry. Four scenarios were developed for the. platinum-mining industry. “Sunshine forever” describes a world characterised by a coincidence of strong economic conditions and high demand for PGMs driven by the rapid increase in emission legislation. Tornado proposes unprecedented economic growth rates, especially in China and India, creating an insatiable demand for energy driving the search for reliable and cheap energy sources.

Tsunami describes depressed economic conditions in a downward spiral. This scenario is characterised by low margins and cash flow, low share prices, minimal investor interest and restricted access to capital. In the last scenario, perfect storm, difficult economic conditions serve to drive innovation. The overall result is that difficult times give way to more encouraging conditions.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The key uncertainties of the platinum-mining industry which will impact on the industry over the next 10–15 years were investigated. Future plausible scenarios were subsequently generated.

6.2 Conclusions of the Study

Global Economic Performance and Emissions Legislation were identified as the. key drivers that will have an impact on the platinum industry over the next 10–15 years. This shows that the forces of greatest strategic significance for the platinum industry relate to two different environmental issues. The first is an economic issue and the other is a regulatory issue. The forces show the trend in which the industry is moving and thus highlight what the executives of the mining industry need to focus on. The subsequent strategic scenarios of the platinum-mining industry were identified as follows:

- Scenario 1: Sunshine Forever
- Scenario 2: Perfect Storm
- Scenario 3: Tsunami , and
- Scenario 4: Tornado

These scenarios provide a perspective of what the platinum-mining industry may have to face within the next 10 to 15 years. The scenarios confirmed that an industry is exposed to a turbulent environment when its environment is dynamic, unpredictable, and driven by continuous societal and technological change.

6.3 Recommendations

This study has highlighted several issues that platinum mining industries need to focus on. We now know what the key drivers are; the next question is “Now what?” As seen previously, the industry suffered considerably during the economic crisis although it is presumably now on the way to recovery. However, history repeats itself and, according to this study, there is the possibility of another wave of a recession. How best can the industry prepare itself for this? The question is not whether it will happen again but how best to prepare and weather the storm if it comes.

“*The signs of an impending crisis often lie all around us, yet we still don’t see them. Fortunately, there are ways to spot danger before its too late” (Watkins and Bazerman 2003).*

This is a quote from a published article on predictable surprises. The article highlights some of the biggest disasters in some industries due to uncoordinated, reactionary, and ultimate failure, revealing a lack of foresight and planning. An example is given of Shell company that, even with all the warning signs, the company never saw the calamity coming. Despite companies having thoughtful managers and robust planning processes, even the best run companies are frequently caught unaware by disastrous events, where events that should have been anticipated and prepared for. These predictable surprises may cause damage that take years to repair or worse off, the industry may never recover.

This is where a scenario study like this, becomes useful for the platinum mining industry. The results of this study should form the basis for the design of preventive and preparatory measures. Combined with risk analysis, this scenario study may provide invaluable insights for the platinum-mining industry. Industry foresight must be informed by deep insight into trends in lifestyle, technology, demographics etc but foresight rests as much on imagination as on prediction (Bower and Christensen 2003). Developing industry foresight requires more than good scenario planning, hence this study proposes the following:

6.1.1 Scenario signposts

What events should we look for or variables should we track to determine which scenario is emerging over time? What important signals are platinum mining companies rationalising away and how do these companies identify important signals? Below is a list of proposed signposts and their significance as an early indicator in monitoring changes relevant to the scenarios. No signpost will unambiguously confirm the emergence of a single scenario, but collectively the signposts should indicate which scenarios seem to be emerging and which are not (Postma and Liebi 2005). The difficulty is assembling seemingly random incidents into a coherent picture and distinguishing between credible warnings and probable false alarms. The goal is to prevent strategic surprises. Executives need to move towards foresight-driven strategic planning to gain better insights (Schoemaker et al. 1992). Therefore, platinum-mining industries need to use sign-posting to plan and strategise for times of turbulence.

Table 4: Signposts for the Platinum-Mining Industry

SIGNPOST	SIGNIFICANCE
Commodities/metal prices index	Rising: Sunshine Forever
	Falling: Tsunami/Perfect Storm
Investment in new mining technology	Increasing: Sunshine Forever
	Decreasing: Tsunami/
Global economic growth rates	High Sunshine Forever
	Low Tsunami/Tornado
Mining Rights Act	Constant Revisions: Tornado
	No revisions/Perfect Storm
Bankruptcies	Sharp increases: Tsunami
Growth of green technologies	Rising: Sunshine Forever/Tornado
	Falling: Tsunami/Perfect Storm
Pressure on climate changes	Rising: Tornado
	Falling: Tsunami/Perfect Storm
Speed of implementation of new emission legislation	Rising: Sunshine Forever
	Falling: Tsunami/Tornado
Population growth	Increasing: Sunshine Forever
	Decreasing: Tsunami
Substitution	Increasing: Tornado
	Reducing Sunshine Forever
Substitution	Rising: Sunshine Forever
	Falling: Tsunami/Perfect Storm
Growth of vehicle manufactured	High: Sunshine Forever
	Falling: Tornado

Scenario methodology has always been a subjective topic. In this study, a qualitative methodology was used which involved a structured interview. Several methods are highlighted in the literature (Ratcliffe 2002); however there is no right or wrong method, only limitations within each method. It is recommended that for, similar research, a workshop be used as this will allow participants to fully engage and determine the key driving forces, thus giving them full ownership of the scenarios. Limitations existed in utilising the Delphi technique as respondents would be tired and may not respond to the second or third round. Timing and knowing the availability of the respondents in advance would reduce time wastage.

6.4 Suggestions for Further Research

Finally, scenarios also serve to raise questions. Questions that another researcher may like to address are:

1. What are the key insights from these scenarios?

2. What are the key challenges that emerge from each scenario?

3. What actions are needed to address these challenges and/or to assist in achieving a more desirable future?

4. What are the implications if these actions are not taken, the do nothing option?

Possibly, look at the importance of signposting in scenario analysis.

REFERENCES

Alcamo, J., van Vuuren, D., Ringler, C., Alder, J., Bennett, E., Lodge, D., Masui, T., Morita, T., Rosegrant, M., Sala, O., Schulze, K., Zurek, M., Eickhout, B., Maerker, M. and Kok, K. (2005) 'Methodology for developing the MA scenarios', In Carpenter, S Pingali, P. Bennett, E. and Zurek, M. (eds.) *Ecosystems and Human Well-being: Scenarios, Volume 2*, Millennium Ecosystem Assessment, Island Press, USA, pp. 145-172

Alcamo, J. (2001) Scenarios as tools for the international assessments, *Expert's Corner Report: Prospects and Scenarios, No. 5*, European Environment Agency, Copenhagen.

Aligica, P. D. (2005) Scenarios and the growth of knowledge: Notes on the epistemic element in scenario building, *Technological Forecasting and Social Change*, 72, pp. 815-824.

Andres, D. (2002) *The Future of PGMs in the Auto Industry*. The LBMA Precious Metals Conference, San Francisco, pp. 51-54.

Anglo Platinum Annual Report, 2007: www.angloplatinum.com

BASF: www.basf.com

Bloxham, L. (2009). The impact of CO^2 legislation on PGM demand in autocatalysts. *Platinum Metals Review*, (3), pp 179-180.

Bower, J. L; Christensen, C. M. (1994) Disruptive Technologies: Catching the Wave, *Harvard Business Review*, pp. 43-54.

Bradfield, R., Wright, G., Burt, G., Cairns, G. and van der Heijden, K. (2005) The origins and evolution of scenario techniques in long range business planning, *Futures*, 37 pp. 795-815.

Bruce, E and Das S. (2002) *Assessment of Platinum availability for advanced fuel-cell vehicles*, Transportation Research Record, 1815-2002, pp 99-104.

Chermack, T.J (2003) A methodology for assessing performance-based scenario planning, *Journal of Leadership and Organisational Studies*, Fall 2003, 10 (2), pp. 55-63.

Chermack, T. and Lynham, S. and Ruona, W. (2001) A review of scenario planning literature, *Futures Research Quarterly*, 17 (2), pp. 7-31.

Chevalier, P. (2004) *Platinum Group Metals*. Canadian Minerals Yearbook.

Clarke, B. Forrest, S. and Ryan, A. (2008) Upcoming economic hurdles for new South African platinum supply In *Third International Platinum Conference "Platinum in Transformation*", Sun City, South Africa, The Southern African Institute of Mining and Metallurgy, pp. 407-412.

Coates, J. F. (2000) From my perspective: Scenario Planning, *Technological Forecasting and Social Change*, 65, pp. 115-123.

Cornford, T. & Smithson, S. (1996). Project Research in Information Systems: A Student's Guide. London: Macmillan Press Ltd.

Cornelius, P., Van de Putte, A. and Romani, M (2005) Three decades of scenario planning in Shell, *California Management Review*, 48 (1).

Courteny, H., Kirkland, J. and Viguerie, P. (1997) Strategy under uncertainty, *Harvard Business Review*, pp. 67-79.

Creswell, J. W. (1994). *Research Design: Qualitative & Quantitative Approaches,* London: SAGE Publications.

Crisp, K. (2005) *Platinum Group Metals – strategic roles*. The LBMA Precious Metals Conference, Johannesburg, pp.71-74.

Creamer Research. (2007, 2008) *Platinum mining in South Africa*, www.researchchannel.co.za

Davis, D. (2008, 2009) *Platinum Supply and Demand*, Metals and Mining, Credit Suisse Standard Securities, Johannesburg

Dixon, J. (2009) *The global economic crisis, worldwide impact on mining companies*, Mine Africa conference.

Duncan, J. (2009), *The global economic crisis – worldwide impact on mining companies*, Toronto Newspaper, pp. 1-4.

Engelbrecht, G. and Anderson S, (2008) Citi Group Industry report. Global vehicles sales wrap, May 2008.

Fahey, L. (2003) Competitor scenarios, *Strategy and Leadership*, 31 (2), pp. 32-44.

Garland, N.L. and Milliken, J. (2002) Platinum: Too precious for fuel cell vehicles? *Future Car Congress*, Arlington, Atlanta, June 3-5.

Genc, B. (2009) Where is platinum heading? In *Third International Platinum Conference "Platinum in Transformation*", Sun City, South Africa, The Southern African Institute of Mining and Metallurgy, pp. 401-406.

George, W. M. (2006) Platinum Group Metals. USGS Minerals Handbook..

Gilreath, P., Singh, B. N. and Rastgoufard, P. *Fuel cell technology: economic, social and political aspects*, IEEE Region 5 Annual Technical Conference, 2003, pp 29-32.

Glenn, J. (1994) Introduction to the Futures Research Methodology Series, In Glenn, J. and Gordon T. (eds.) *Futures Research Methodology. Version 2.0*, AC/UNU Millennium Project. United Nations University Press, pp. 1-45.

Godet, M. and du Roubelat, F. (2003) Creating the future: The use and misuse of scenarios, *Long Range Planning*, 29 (2), pp. 164-171.

Godet, M. (2000) The art of scenarios and strategic planning: Tools and pitfalls, *Technological Forecasting and Social Change*, 65, pp. 3-22.

Godet, M. (2000b) How to be rigorous with scenario planning: The scope and limits of formalities methods, *Futuribles*.

Gordon, T. and Glenn, J. (2004) *Integration, Comparisions and Frontiers of Futures Research Methods*, EU-US Seminar: New Technology Foresight, Forecasting and Assessments Methods, Seville, 13-14 May 2004.

Gordon, T. (1994) The Delphi Method, In Glenn, J., T. Gordon (eds) *Futures Research Methodology, Version 2.0*, AN/UNU Millenium Project. United Nations University Press.

Gordon, A. (2008) *Using trends and Scenarios as tools for Strategy Development: Shaping the future of your enterprise*, Publicis Corporate Publishing, Erlangen Press.

Hill, M. (2008) *Power shortage won't pull the plug on resources boom,* www.miningweekly.co.za.

Hill, M. (2008) *Power crisis impact on mining,* www.miningweekly.co.za.

Honda. 2007 Honda Civic Hybrid Gasoline–Electric. (2007), [http://www.hondacars.com/models/overview/hybrid.

Jollie, D. (2008) *Platinum 2008*, Johnson Matthey.

Jollie, D. (2009) *Platinum 2009*, Johnson Matthey.

Kahn, H. (1973) 'The alternative world futures approach', in Tugwell F. (ed.) *Search for Alternatives: Public Policy and the Study of the Future*, Witrop Publishers, Cambridge, MA.

Kipps, D. (2007) *The likely future driving forces and key success factors of the South African online media industry*. MBA Research Report, Wits Business School.

Leedy, P. and Ormond, J. (2001) *Practical Research: Planning and Design*, Upper Saddle River, New Jersey: Merrill Prentice Hall.

Loferski, P.J. (2008) *USGS Minerals Handbook*.

Loo, R. (2002) 'The Delphi method: A powerful tool for strategic management, policing', *An international Journal of Police Strategies and Management*, 25 (4), pp. 762-769.

May, G. H. (1996) *The future is Ours: Foreseeing, Managing and Creating the Future*. London: Adamantine Press.

Mercer, D. (1995) Simpler scenarios, *Management Decisions*, 33 (4), pp. 32-40.

Mercer, D. (1995b) Scenarios made easy, *Long Range Planning*, 28 (4), pp. 81-86.

Miller, K. D. and Waller H. G. (2003) Scenarios, real options and integrated risk management*, Long Range Planning*, 36, pp. 93-107.

Markoczy, L. and Goldberg J. (1995) A method for eliciting and comparing causal maps, *Journal of Management*, 21 (2) pp. 305-333.

More, H. (2003) Scenario planning or does your organisation rain dance? *New Zealand Management*, May 2003.

Morrison, J and Wilson, I. (1997) Analysing environments and developing scenarios in uncertain times, in Peterson, M. W., Dill, D.D,, Mets L.A. and Associates (Eds.), *Planning and Management for Changing Environment*. Jossey-Bass, San Francisco.

Neilson, R.E. and Stouffer, D. (2005) 'Narrating the vision: Scenarios in action', *The Futurist*, 39 (3), pp. 26-31.

Nel, W.P. (2004) The diffusion of fuel cell vehicles and its impact on the demand for platinum group metals, *International Platinum Conference "Platinum Adding Value",* South African Institute of Mining and Metallurgy, pp. 287-328.

O'Brien, F. A. (2003) 'Scenario planning – lessons for practice from teaching and learning', *Journal of Operational Research*, 34 (2), pp. 442-448.

Porter, M. E. (1985) *Competitive Advantage*. New York: Free Press.

Porter, M. E. (2008) The five competitive forces that shape strategy, *Harvard Business Review*, pp. 1-18.

Postma, T. and Liebl, F. (2005) How to improve scenario analysis as a strategic management tool, *Technological Forecasting and Social Change*, 72, pp. 161-173.

Powell, C. (2003) 'The Delphi technique: Myths and realities', *Journal of Advanced Nursing*, 41 (4), pp. 376-382.

Ratcliffe, J.S. (2000) 'Scenario building: A suitable method for strategic construction industry planning', *Property Management*, 18 (2), pp. 127-144.

Ratcliffe, J. (2002) Scenario planning: Strategic interviews and conversations, *Foresight*, 4, pp. 19-30.

Roux, A. (2009) Planning and Strategising during Turbulence, Institute for Futures Research, 7 (2), pp. 1-4.

Schoemaker, P.J.H., van der Heijden, J. and Cornelius A.J.M. (1992), 'Integrating scenarios into strategic planning at Royal Dutch/Shell', *Planning Review*. 20 (3), p. 41.

Schoemaker, P.J.H. (1992) Multiple scenario development: Its conceptual and behavioural foundation, *Strategic Management Journal*, 14, pp. 193-213.

Schoemaker, P.J.H. (1995) 'Scenario planning: A tool for strategic thinking', *Sloan Management Review*, pp. 25-39.

Schoemaker, P.J. H. and van der Heijden, K. (1992) Integrating scenarios into strategic planning at Royal Dutch/Shell, *Planning Review*, 20 (3), pp. 41-46.

Schoemaker, P.J.H. (1991) When and how to use scenario planning: A heuristic approach with illustration, *Journal of Forecasting*, 10, pp. 549-564.

Schwartz, P. *The Art of the Long View: Paths to Strategic Insight for Yourself and Your Company,* Doubleday, New York, 2006.

Schwartz, P. (2005) 'Scanning the periphery'*, Harvard Business Review*, Nov-Dec.

Selin, C. (2006) Trust and the illusive force of scenarios, *Futures*, 38, pp.1-14.

Smith, G. L., Surujhlal, S. N. and Manyuchi, K. T. (2009) 'Strategic mine planning – Communicating uncertainty with scenarios', In *Third International Platinum Conference "Platinum in Transformation*", Sun City, South Africa, The Southern African Institute of Mining and Metallurgy, pp. 335-342.

Stillwell, L. C. (2009) 'Platinum, electricity and the economy', In *Third International Platinum Conference "Platinum in Transformation*", Sun City, South Africa, The Southern African Institute of Mining and Metallurgy, pp. 307-314.

Story, V, Hurdley, L., Smith, G. and Saker, J. (2001) Methodological and practical implications of the Delphi Technique in marketing decision-making: A re-assessment, *The Marketing Review*, 1, pp.487-504.

Sunter, C. (1996) *The High Road, Where are We Now?* Cape Town: Human Rousseau Tafelberg.

Sunter, C (1998) *The Mind of a Fox*. Cape Town, Human Rousseau Tafelberg.

Sunter, C. and Ilbury C. (2008) The world and South Africa in the 2010s, *Leadership*.

The Futures Group (1994) Scenarios, In Glenn, J. and Gordon T. (eds) *Futures Research Methodology, Version 2.0,* AC/UNU Millennium Project. United Nations University Press.

Tonn, B. (2005) Imprecise probabilities and scenarios, *Futures*, 37, pp. 767-775.

Van der Heijden, K. (2005) Scenarios: The art of strategic conversations (2nd ed), New York: Wiley.

Van't Klooster, S. and van Asselt, M. (2006) Practising the scenario-axes technique, *Futures*, 38, pp.15-30.

Wack, P. and Duncan, N.E. (1994) Scenarios designed to improve decision making, *Planning Review*, 22 (4), pp. 18-27.

Wack, P. (1985) Scenarios: Uncharted waters ahead, *Harvard Business Review*, Sept-Oct.

Wack, P. (1985b) Scenarios: Shooting the rapids, *Harvard Business Review*, Nov-Dec.

Watkins, M. D; Bazerman, M. H. (2003) Predictable Surprises: The Disasters you should have seen coming, *Harvard Business Review*, pp. 5-12.

Watts, J. C., Forrest, S. A., Clarke, B. and Atilan, O. (2009) Future shifts in PGM demand – the impact of technological and economic scenarios on future metal demand, In *Third International Platinum Conference "Platinum in Transformation*", Sun City, South Africa, The Southern African Institute of Mining and Metallurgy, pp 395-400.

Wilburn, D. R. and Bleiwas, D. I. (2007) *Platinum Group Metals – World Supply and Demand*, USGS Minerals handbook.

Yang, C. (2009) An impending platinum crisis and implications for the future of the automobile, *Energy Policy*, 37. pp. 1805-1808.

APPENDIX A: LETTER TO REQUEST EXPERT REVIEW

(on WBS letterhead and supervisor's name)

Dear Mr X (Name inserted),

My name is Patience Mpofu and I am a 3rd year MBA student at Wits Business School. As a requirement for completion of my MBA, I am currently conducting a research entitled, "Future Plausible Scenarios for the Platinum-mining industry". The research that I am conducting seeks to explore the key driving forces that will impact on the platinum-mining industry in the next ten to fifteen years. Due to the exploratory nature of this research, 20 leading diverse experts with extensive industry knowledge, have been selected to be part of this study namely from, senior executives of major platinum producers, researchers from leading academic institutes, mining analysts, strategy consultants and scenario experts. You are therefore kindly invited to participate as a leading expert in this field.

The questionnaire is estimated to last no longer than 30 minutes of your time. Your time and contribution to this research will be highly appreciated. Feedback will be given on the final and comments, critics, evaluation or further thought will be important for adding value to this research. Your valuable inputs will be summarised and cited in the report. I would like to guarantee anonymity, neither your name nor your institute/company will be linked to any statements or comments made. The final report will be available upon request. I will greatly appreciate if you could submit your first round of inputs by Thursday the 25th June 2009.

Find attached the questionnaire for your review prior to the meeting and once again, thank you for your time and have a nice day.

Yours Sincerely,

Patience Mpofu: Part time MBA student 2006-2009

Email Address: pmpofu@angloplat.com

APPENDIX B: QUESTIONNAIRE TO EXPERTS

Scenarios for the platinum-mining industry

Please complete the questionnaire and return it via email: pmpofu@angloplat.com
If you have any queries or would like further information about this research project, please contact the researcher.

Name:	
Organisation:	
Role	

Question:

Please list the key driving forces that you believe will significantly affect the platinum-mining industry in the next ten to fifteen years (should be forces beyond company control and can be drawn from the PESTEL framework).

Example:

Force: Wide adoption of alternative energy technologies (e.g. Fuel cells). *Brief description/explanation*: As oil prices and cost of polluting keeps increasing, alternatives will become increasingly attractive. *Possible outcome*: PGM based fuel cell adoption increase hence increased platinum demand. *Any related forces/other comments*: This force is closely linked to platinum demand, as high use of fuel cells may imply growth end uses of platinum etc.
Force: *Brief description/explanation*: *Possible outcome*: *Any related forces/other comments*:

APPENDIX C: RESPONSES

Name:	**Expert 1**
Organisation:	**Anonymous 1**
Role:	**Anonymous 1**

Force: Rise of developing world middle-income population

Brief description/explanation: Middle-income consumers purchase motor cars

Possible outcome: As middle-income numbers expand significantly, the demand for vehicles could grow exponentially (and therefore also the demand for fuel cells).

Any related forces/other comments:

Force: Regulatory/ legislative framework

Brief description/explanation: Calls for nationalisation by some members of the ruling alliance could affect the feasibility and attractiveness of mining platinum.

Possible outcome: Nationalisation is rejected, but not without some degree of acrimony.

Any related forces/other comments:

Name:	**Expert 2**
Organisation:	**Anonymous 2**
Role	**Anonymous 2**

Force: Labour

Brief description/explanation: Labour accounts for >50% of mining costs and has been a cause of significant inflationary cost pressures in the sector

Possible outcome: Rising cost pressures could yield SA PGM production as uncompetitive and force metal prices higher and reduce end-use demand through driving substitution

Any related forces/other comments:

Force: Ore Quality

Brief description/explanation: South African mining houses are having to mine deeper for lower grade ore, increasing the cost structure of the industry

Possible outcome: Rising cost pressures could yield SA PGM production as uncompetitive and force prices higher and reduce end-use demand through driving substitution

Any related forces/other comments:

Force: ZAR strength/volatility

Brief description/explanation: While end-use demand is denominated in US$, South African supply is denominated in ZAR (due to the cost base)

Possible outcome: Rising cost pressures could yield SA PGM production as uncompetitive and force prices higher and reduce end-use demand through driving substitution – a weaker ZAR reduces the required US$ metal prices needed for companies to break-even and generate returns allowing for greater production and end-use demand.

Any related forces/other comments:

Name:	**Expert 3**
Organisation:	**Anonymous 3**
Role	**Anonymous 3**

Force: Alternative transportation modes / automotive technology (alternative to catalytic converter)

Brief description/explanation: If the demand for Pt in the transport industry were drastically reduced, it would significantly negatively affect demand

Possible outcome: Reduced Pt demand

Any related forces/other comments: >Linked to consumer preference and policy positions, significantly influenced by global concerns around Climate Change

Force: Protracted global economic recession

Brief description/explanation: Current recession continues in waves for next half-decade, exacerbated by instability in the east and protectionist policies in the major world economies – affects global markets for next decade. *Possible outcome*: Pt supply outstrips demand *Any related forces/other comments*: The effects are not necessarily just constriction – possibly new geo-political formations, economic logic, etc…
Force: Resource nationalisation *Brief description/explanation*: Driven, particularly in less democratic and newly formed states (including African, former Soviet, and Asian states, …) *Possible outcome*: Limited expansion of private mining, Constriction of industry *Any related forces/other comments*: > May lead to negotiations of terms for mining rights, especially in respect to beneficiation and community benefits

Name:	**Expert 4**
Organisation:	**Anonymous 4**
Role	**Anonymous 4**

Force: global economic growth / macro economic forces *Brief description/explanation*: The rate of growth of the global economy and the respective points of growth – developed or emerging economies drives PGM demand. The three major sectors of PGM consumption are auto catalysis, industrial applications and jewellery. These are directly linked o economic activity – national level for the first two and personal for jewellery. *Possible outcome*: A decline in economic activity in the countries concerned with or adhering to the "euro emissions" protocols results in a decline in PGM consumption. A drop in disposable income results in a drop in jewellery sales. Movements in the macro economy affect demand = direct casual link.. *Any related forces/other comments*: This casual link is moderated / increased by shifts in the core application of PGMs for catalysis eg increased efficiency of use (reduced autocat loadings) reduces unit consumption. Conversely the development of new applications for PGMS eg Ru in memory drives and

Pd for inhibiting fruit ripening increases consumption

Force: Application of PGMS – this force is directly related to the related forces comment for the macro economic driver above

Brief description/explanation: Consumption is driven by volume and by the pervasiveness of the use of PGMs. PGM core application is as a catalyst owing to the Group specific chemical properties. Development of new techniques may reduce consumption (increase efficiency of use) but the key threat would be substitution by another material that can achieve similar catalytic efficacy.

Possible outcome: Reduced necessity for PGMS (ie substitution) will result in reduced consumption in certain applications

Any related forces/other comments:
As per my opening comment

Force: Increased efficiency of recycling of PGM's

Brief description/explanation: Currently not all PGM's that are produced are recycled. There is a net 'consumption' on an annual basis resulting from inefficient recycling processes, manufacturing techniques, legislation and social drivers. Industrial recycling is largely efficient with the majority of material re-entering the recycle stream, Auto catalyst recycling efficiency is a function of point of use of vehicles, legislation, recycling facilities and social pressure. High recycle occurs in Europe, N America, Japan but is virtually non existent in Africa, most S America and most of Asia! Jewellery recycle is minimal at present as Pt is seen as a future store of value.

Possible outcome: increased recycling – collection and recovery provides a lower cost, more "cycle robust" source of metal for major consumers. Major consumers integrate recycling into their business models and reduce demand for new metal to net market growth. Slow market growth means less demand, placing pressure on primary producers. Selective extraction of orebodies results which reduces overall mineral resource extraction efficiency and reduced potential value from the resource – future generations are left poor grade, "difficult" orebodies in a 'peak' platinum situation (similar to the peak oil scenario)

Any related forces/other comments:

Name:	**Expert 5**
Organisation:	**Anonymous 5**
Role	**Anonymous 5**

Force: Consumer confidence in developed markets

Brief description/explanation: Consumer confidence is key in determining purchase decisions of consumer durables like motor cars, which are the single biggest demand driver for PGMs.

Possible outcome: A prolonged Western recession would suppress consumer confidence and delay car purchase decisions as long as possible, or lead to buying smaller cars, perhaps leading to reversal of market share growth of hybrid cars (US) and diesel powered cars (EU) and hence a reduction of PGM usage per car and a shift from Pt (diesel) to Pd (petrol).

Any related forces/other comments: Access to finance for consumers, as that would also impact on their ability to buy a new motor car.

Force: Successful application of low-level PGM applications in autocatalysts.

Brief description/explanation: Several Japanese carmakers have released new models with significantly lower PGM load, applying nanotechnology to allow for thrifting.

Possible outcome: If these cars allow the maintenance of acceptable exhaust emissions over the lifetime of the car, this trend will surely gain further ground. This would erode PGM demand in its biggest application area.

Any related forces/other comments: Other automotive research aiming to reduce PGM cost in catalysts, by changing the metals used and reducing their specific consumption.

Force: Demise of the junior mining companies in the financial crisis.

Brief description/explanation: Many juniors are facing extremely difficult conditions with accessing financing to allow these companies to continue with their project development. This is particularly true for early stage projects and less attractive ones.

Possible outcome: More than half of all junior mining companies are likely to disappear as going concerns due to running out of cash. Some of the underlying resources will trade hands and may be developed further under new ownership. This trend will reduce the potential for the industry to grow long-term supply and thus meet future needs when PGM growth in developing markets picks up and Western

markets rebound.

Any related forces/other comments: Slashing of exploration budgets of major players and delays or cancellations of projects that were meant to be developed before the crisis would also impact supply growth.

Name:	**Expert 6**
Organisation:	**Anonymous 6**
Role	**Anonymous 6**

Force: power shift to society and geopolitically

Brief description/explanation: the dominant power moves away from government and big business as has traditionally been the case to society. The "West" no longer yield the world universal power as new power blocks have emerged: BRICA –Brazil, Russia, India, China and India

Possible outcome: society demands better practices and standards in business; sources of capital are now wider which allows new business models to emerge.

Any related forces/other comments: the demand and supply situation for PGM's remaining high but with society demanding more on how they are mined and marketed.

Force: The emergence of religion as a global force

Brief description/explanation: Religious believes become such a strong force shaping, societal, political and business practices. The world gets polarised on this basis and this determines and threatens global peace and security.

Possible outcome: global political instability, wars (civil wars and interreligious wars)

Any related forces/other comments: the force influences how business will not thrive or how it could thrive is religious harmony is maintained.

Force: Climate change

Brief description/explanation: in future, we will get to understand the full impacts of climate change. As this

becomes clearer it will inform new policy directions and priorities

Possible outcome: cleaner fuel technologies, a plus to the use of platinum; stricter environmental regulations, a plus for the use of PGM's

Any related forces/other comments: this force encourages usages PGM.

Name:	**Expert 7**
Organisation:	**Anonymous 7**
Role	**Anonymous 7**

Force: Legislation-driven catalytic control of automotive and non-road engine emissions

Brief description/explanation: Global legislation continues to develop regarding acceptable levels of engine pollution. Automotive catalyst demand will be driven largely by increased number of vehicles globally, whilst non-road catalyst demand will be produced by new waves of legislation

Possible outcome: Increased use of PGMs, notably platinum, palladium, and rhodium

Any related forces/other comments: Engine technologies will develop offering higher efficiency/less pollution per unit distance travelled, but all currently conceivable major technology developments for the 10 – 15 year horizon will require PGMs catalysts in one form or another

Force: Investor community interest covers a broader range of commodities, including PGMs

Brief description/explanation: A probable fall-out from the global banking sector and economic crisis is investment in a broader range of commodities beyond gold, bonds, and company equities. Platinum and palladium are likely to attract such interest with a wider audience and in different product forms from those currently seen.

Possible outcome: Large investments and disinvestments which will lead to price volatility and increasingly make price more dependent on market sentiment than on supply/demand fundamentals.

Any related forces/other comments: Probably not a positive development for the platinum-mining industry as it makes planning more difficult and exposes business models to the vagaries of price elastic investor sentiment

Force: Mining cost inflation and lack of skilled workforce

Brief description/explanation: The lack of workers available to meet the need for growing PGMs supply in an ever more complex mining environment (eg greater depth) will lead to mining cost inflation well ahead of CPI growth. This in turn will damage productivity which will drive unit costs still higher.

Possible outcome: Rationalisation of mine industry structure, with disappearance of higher cost producers. PGMs price base, although subject to volatility due to market sentiment, will become cost rather than market driven.

Any related forces/other comments:

Name:	**Expert 8**
Organisation:	**Anonymous 8**
Role	**Anonymous 8**

Force: Increase in Secondary Recycling

Brief description/explanation: Due to increase in safety related deaths in the mines, more companies to embark on secondary supply, autocatalysts recycling.

Possible outcome: An increase in secondary supply dominated particularly in China and India as new emission legislation comes into play.

Any related forces/other comments: Recycling rates currently very low in China, India and the rest of the world.

Force: Legislation on emission control

Brief description/explanation: Due to increase in global warming, there will be an increase in even stricter legislation around emission control.

Possible outcome: PGM demand may or may not increase depending on the technological front of greener cars.

Any related forces/other comments: Other automotive research aiming to reduce PGM cost in catalysts, by changing the metals used and reducing their specific consumption.

Force: Fuel Cell Technology Uptake

Brief description/explanation: Fuel cell technology will take over replacing all gasoline and diesel vehicles. This will be the future for greener technology.

Possible outcome: PGM demand may exceed supply and securities around the ability of platinum companies to meet demand may necessitate adoption f other non-Pt based technology.

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Force: ETFs demand surging to unprecedented levels

Brief description/explanation: ETF demand for Pt and Pd increase and destabilise supply and demand dynamics resulting in price volatility.

Possible outcome: Price volatility and un sustained demand of PGMs.

Any related forces/other comments:

Name:	**Expert 9**
Organisation:	**Anonymous 9**
Role	**Anonymous 9**

Force: Downstream processing and refining

Brief description/explanation: Downstream processing is a barrier - requirement for smelter capacity of X for a viable investment). Currently there is no major independent smelting and refining capability – new entrants will largely depend on current incumbents' capacity.

Possible outcome: The multitude of juniors and intermediate Pt miners could provide an opportunity for an independent processing facility. Alternatively, through backward integration, customers could provide a facility to ensure constancy of supply.

Any related forces/other comments:

Force: New consolidated Entrant

Brief description/explanation. Government policy has favoured/promoted new entrants, through empowerment partnering for new order rights. Although a minimum of 26% was required – a significant leverage for growth and consolidation to form a new major exists. This threat could be exacerbated if

this were coupled with the financial resources of an existing major.

Possible outcome: Industry consolidation

Any related forces/other comments:

Force: Resource Nationalisation

Brief description/explanation: The drive of emerging economies to get access to resources through foreign direct investment and share ownership as is being pursued by China, India and more recently Russia.

Possible outcome: Foreign governments funding access to resources.

Any related forces/other comments: Resource Nationalisation

Force: Skills shortage

Brief description/explanation: With a shortage of skilled labour (FEL drivers, electric drill operators, technical skills), many more lucrative opportunities are available, making retention costly.

Possible outcome: Increasing labour costs.

Any related forces/other comments:

Force: Alternate Energy Sources

Brief description/explanation: Alternate energy sources for transportation (batteries, etc.).

Possible outcome: Reduced demand, making metal obsolete in time, unless new applications are investigated.

Any related forces/other comments:

Force: Cannibalisation of Platinum with Palladium

Brief description/explanation: High Pt prices drive substitution of Pt with Pd. Additionally, significant new strides made in thrifting will reduce PGM loading on Catalytic converters

Possible outcome: Reduced demand.

Any related forces/other comments:

Force: Economic performance

Brief description/explanation: Continued high demand (and constrained supply) for tyres, explosives, fuel, timber, machinery, etc are contributing to high opex escalations

Possible outcome: Increasing operating costs

Any related forces/other comments:

Name:	**Expert 10**
Organisation:	**Anonymous 10**
Role	**Anonymous 10**

Force: Industry consolidation

Brief description/explanation: Consolidation of the PGM industry in the creation of equally sized large corporations, without an outright industry leader.

Possible outcome: Industry restructuring and possible new business models.

Any related forces/other comments:

Force: Technology change

Brief description/explanation. Adoption of platinum based electric fuel cells as zero-emissions technology of the future. However competing technologies could displace PGM demand in the automotive segment. Hybrids, plug-in hybrids, Hydrogen internal combustion, battery electric and fuel cell electric could all change the PGM industry structure.

Possible outcome: Possible downward or upward pressure on PGM demand due to limited scope for tightening of emission standards and smaller vehicles

Any related forces/other comments: Demand of PGM in marine transport, commercial aircraft and power generation and locomotives due to legislation as key driver.

Force: Legislation: Drive for clean energy

Brief description/explanation: This will be driven primarily by global warming necessitating the need for

more efficiency in energy use.

Possible outcome: Changing societal values and increased environmental pressures. New rules of game, energy diversification based on cleaner greener energy sources. Carbon footprint becomes the norm on a daily basis

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Name:	**Expert 11**
Organisation:	**Anonymous 11**
Role	**Anonymous 11**

Force: Increasing adoption of electric and hybrid vehicles

Brief description/explanation: Increased government funding (developed countries) into green technologies including lithium ion batteries and the resulting increased commercial viability of lithium ion batteries in the powering of motor vehicles will result in a greater percentage of sales of hybrid and electric vehicles

Possible outcome: Hybrid vehicles continue to gain market share (PGM demand neutral) however electric vehicles begin to make a noticeable impact on sales of diesel and petrol powered vehicles in the next 15 years and reduce demand for PGMs

Any related forces/other comments:

Force: Increased supply of Platinum, Palladium and Rhodium from secondary supply sources

Brief description/explanation: Legislation in EU requiring recycling of vehicles and increase in recycling of vehicles in USA will result in substantial increases in supply of Pt, Pd and Rh from secondary sources.

Possible outcome: In 10 to 15 years secondary supply could account for more than a quarter of all Pt, Pd and Rh supplied.

Any related forces/other comments:

Force: Fuel Cell Technology

Brief description/explanation: Increasing use of fuel cell technology particularly stationary fuel cells as a clean energy source – use supported by continued R&D and possibly legislation in developed countries

Possible outcome: Increased demand for Pt for use in fuel cells becoming significant in 15 years

Any related forces/other comments:

Force: Increased capital and operating costs in RSA mines and projects

Brief description/explanation: Shallow, low cost, good grade ounces are progressively being depleted and replaced by deep, high cost ounces. Replacement ounces require significant capital investment to sink deep shafts and develop related infrastructure. Difficult ground conditions and lower grades result in reduced production and increasing costs on a cost per ounce basis.

Possible outcome: Result is closure of unprofitable shafts and reduced production and the deferment of capital to develop shafts to produce replacement ounces resulting in a decrease in supply.

Any related forces/other comments:

Force: Increase in ratio of UG2 ore mined in relation to Merensky ore

Brief description/explanation: The PGM majors are progressively mining more UG2 as opposed to Merensky ore. Merensky ore with high nickel and copper content is required for the safe and optimal operation of the furnaces operated by the majors

Possible outcome: Focus on newer technology – use of DC furnaces – and focus on PGM projects (or even nickel and copper sulphide deposits) rich in nickel and copper

Any related forces/other comments:

Force: Operational and project execution complexity and risk

Brief description/explanation: Although not specific to the PGM Industry a number of factors have meant that the complexity and risk involved in carrying out mining operations and executing mining projects in Southern Africa has increased. These factors include water scarcity, lack of electricity, prioritisation of SHEC issues, Mining Charter and BEE Codes of Good Practice compliance and regulatory and license requirements

Possible outcome: Reduced production from current operations, project suspensions and delays, increased project hurdle rates to account for increased risk, increased infrastructure and project feasibility costs

Any related forces/other comments:

Name:	**Expert 12**
Organisation:	**Anonymous 12**
Role	**Anonymous 12**

Force: Industry consolidation

Brief description/explanation: Consolidation of the PGM industry in the creation of equally sized large corporations, without an outright industry leader.

Possible outcome: Industry restructuring and possible new business models.

Any related forces/other comments:

Force: Technology change

Brief description/explanation. Adoption of platinum based electric fuel cells as zero-emissions technology of the future. However competing technologies could displace PGM demand in the automotive segment. Hybrids, plug-in hybrids, Hydrogen internal combustion, battery electric and fuel cell electric could all change the PGM industry structure.

Possible outcome: Possible downward or upward pressure on PGM demand due to limited scope for tightening of emission standards and smaller vehicles

Any related forces/other comments: Demand of PGM in marine transport, commercial aircraft and power generation and locomotives due to legislation as key driver.

Force: Legislation: Drive for clean energy

Brief description/explanation: This will be driven primarily by global warming necessitating the need for more efficiency in energy use.

Possible outcome: Changing societal values and increased environmental pressures. New rules of game, energy diversification based on cleaner greener energy sources. Carbon footprint becomes the norm on a daily basis

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Name:	**Expert 13**
Organisation:	**Anonymous 13**
Role	**Anonymous 13**

Force: Economic performance

Brief description/explanation: Economic conditions under which the industry will operate in the future.

Possible outcome: Industry could experience extended periods of strong prices, growth and productivity supporting the economic viability of new mines and enhanced access to capital.

Any related forces/other comments:

Force: Technology change

Brief description/explanation. Adoption of platinum based electric fuel cells as zero-emissions technology of the future. However competing technologies could displace PGM demand in the automotive segment. Hybrids, plug-in hybrids, Hydrogen internal combustion, battery electric and fuel cell electric could all change the PGM industry structure.

Possible outcome: Possible downward or upward pressure on PGM demand due to limited scope for tightening of emission standards and smaller vehicles

Any related forces/other comments: Demand of PGM in marine transport, commercial aircraft and power generation and locomotives due to legislation as key driver.

Name:	**Expert 14**
Organisation:	**Anonymous 14**
Role	**Anonymous 14**

*Force: I*ncreased Recycling of Autocatalysts

Brief description/explanation: Secondary supply coming from recycled autocatalysts increases.

Possible outcome: Supply into market flooded by recycled material impacting on new supply demand

Any related forces/other comments:

Force: Substitution of Platinum in autocatalysts

Brief description/explanation. Increased in Pt substitution by other PGMs or non-Pt based.

Possible outcome: Downward pressure on Pt price

Any related forces/other comments:

Force: Fuel Cell growth

Brief description/explanation: Drive for greener technologies drives the demand for fuel cell technology

Possible outcome: Increased demand for PGMs as fuel cell growth increases

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Force: Inefficient operations

Brief description/explanation: Mines getting deeper, geology complex, grade lower and constraints upstream impacts on profitability of industry.

Possible outcome: Supply constraints hence driving alternative technology and thrifting

Any related forces/other comments:

Force: Double dip recession/prolonged recession

Brief description/explanation: Global recession impacts on the demand for autocatalysts and shifts demand dynamics.

Possible outcome: Shifting industry demand dynamics e.g. increased demand in investment sector and jewellery, economic and financial pressures

Any related forces/other comments:

Name:	**Expert 15**
Organisation:	**Anonymous 15**
Role	**Anonymous 15**

Force: Higher costs/Lower grade with increased UG2 mining

Brief description/explanation: Increased proportions of UG2 reef type will increase the operating costs hence industry structural changes.

Possible outcome: Industry restructuring and possible new business models.

Any related forces/other comments:

Force: Platinum Industry structure: Consolidation

Brief description/explanation. Consolidation of juniors. This threat could be exacerbated if this were coupled with the financial resources of an existing major.

Possible outcome: Shift in industry structure

Any related forces/other comments: Nationalisation of mines by Government

Force: Alternative technologies

Brief description/explanation: The path to zero emissions prompts adoption of new technologies that do not require PGM hence could displace PGM demand

Possible outcome: Complete change in the demand of platinum with newer technologies not requiring any PGMs.

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Name:	**Expert 16**
Organisation:	**Anonymous 16**
Role	**Anonymous 16**

Force: Adoption of alternative technology

Brief description/explanation: Alternative technology driven by legislation.

Possible outcome: Demand for PGMs may/may not decrease.

Any related forces/other comments:

Force: Prolonged recession/Double dip recession

Brief description/explanation. Impact the demand of PGMs

Possible outcome: Downward pressure on demand growth and may result in prolonged mine closures

Any related forces/other comments:

Force: Energy concerns

Brief description/explanation: Shift in use of fuel as fuel price increase drives for alternative electric cars etc

Possible outcome: Substitution of pt based autocatalysts

Any related forces/other comments: Drive for greener technology due to increased legislation control.

Force: Chinese and Indian growth

Brief description/explanation: insatiable demand of PGMs resulting in demand outstripping supply hence concerns of security of supply

Possible outcome: Substitution for either non-Pt based items or other PGMs eg. Pd in autocatalysts.

Any related forces/other comments:

Name:	**Expert 17**
Organisation:	**Anonymous 17**
Role	**Anonymous 17**

Force: Greener New Technology

Brief description/explanation: New technologies driven by legislation.

Possible outcome: Can either increase or reduce demand of platinum but net demand may be an increase in demand

Any related forces/other comments:

Force: ETF's

Brief description/explanation. Exchange Traded funds increased demand

Possible outcome: New business models hence industry restructuring

Any related forces/other comments:

Force: Increased substitution

Brief description/explanation: This may be substitution of Pt by other metals e.g. Pd resulting in higher demand for Pd

Possible outcome: Price increase of Pd

Any related forces/other comments:

Name:	**Expert 18**
Organisation:	**Anonymous 18**
Role	**Anonymous 18**

Force: Climate change

Brief description/explanation: Climate change will drive for even stricter legislations.

Possible outcome: Shifting industry values.

Any related forces/other comments:

Force: Adoption of alternative energy technologies (Fuel cells)

Brief description/explanation. Increasing oil prices and costs of polluting keeps increasing: Alternatives will become attractive

Possible outcome: PGM based fuel cell adoption increase hence increased platinum demand

Any related forces/other comments: This force is closely linked to platinum demand, as high use of fuel cells may imply growth end uses of platinum etc.

APPENDIC D: CONSISTENCY MATRIX

Research problem stated here: What are the future plausible scenarios for the Platinum-Mining Industry?			
Research Question	**Literature Review**	**Source of data**	**Analysis**
What are the key uncertainties that would impact on the platinum mining industries in the next 10 to 15 years?	Gilreath *et al*. 2003, Nel, 2004, Andres, 2002; Bruce and Das, 2002; Garland et al. 2002; Gilreath et al. 2003; Chevalier, 2004; Nel, 2004; Yang, 2009. Schoemaker, 2002; Schoemaker, 1995; Coates, 2000; Courtney et al. 1997; Godet at al. 2000	Scenario Planning Exercise Platinum industry	Causal Loop Methodology Scenario
What are the future plausible scenarios for the platinum-mining industry and the subsequent implications?	Schoemaker, 1992, Schoemaker, 1995, Warren, 1995, Williams and Nicholas 1999; Coates, 2000, de Figueiredo 2000; Godet and Roubelat, 2000, Meisel and Sullivan 2000; Picard 2000; Scott 2000; Winder 2001; Alves 2001; Hunt 2002; O'Brien, 2003, Parker 2004, Chermack, 2005, Bradfield et al. 2005	Scenario Planning Exercise	Scenario Analysis