MODERN MANAGEMENT IN THE GLOBAL MINING INDUSTRY

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MODERN MANAGEMENT IN THE GLOBAL MINING INDUSTRY

ROBIN G. ADAMS

assisted by Christopher L. Gilbert and Christopher G. Stobart

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INVESTOR IN PEOPLE

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About the Authors

Robin G. Adams was born in England in 1946 but was brought up in Bulawayo, now in Zimbabwe. He studied at Oxford where he gained a double first in PPE and was Treasurer of the Oxford Union. He spent most of his adult life working as a Minerals Economist with Citibank, his own company Resource Strategies and the CRU Group both in England and the United States. His work included consulting to mining companies, to fabricating and manufacturing companies as well as to international organizations. He also helped to facilitate investment agreements between host governments and multinational companies, resolve commercial disputes between companies and governments, and was also called upon to provide expert witness testimony on environmental issues related to mining and processing. He died in 2014.

Christopher L. Gilbert is Adjunct Professor at the Bologna Center of the Johns Hopkins School of Advanced International Studies. He previously held professorial positions in London, Amsterdam and Trento. He is a Non-Executive Director of CRU International Ltd.

Christopher G. Stobart worked in the publishing industry and then as a financial journalist before joining CRU International in 1976. He has worked for that company in a variety of capacities since that date.

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Foreword

Robin Adams was an exceptional man and an inspiring force. Our paths first crossed in the 1970s when Robin came to join CRU back in its fledgling days. One could not help being struck by this tall impressive fellow. He had a top first from Oxford in PPE, was self-taught in advanced statistics and maths, and widely read in history, politics and sociology. One of his great gifts was his ability to bring insight and enrichment from many other subjects to his application of economics.

This interdisciplinary approach is in evidence throughout the book you hold in your hand. It forms an introduction to the approach Robin and CRU adopted in different types of assignments; how we applied our methodologies to gain understanding and use the results to help clients manage risks more effectively and better assess likely developments and future trends. Robin was also keenly interested in the forces that engender change in society, industries and markets, both national and local.

CRU was established in 1969 and was the first research company to specialise in metals, minerals and mining, advising governments and corporates active in these sectors. Much of that advice came from applying principles of economic analysis to deal with business challenges that are typical to natural resource industries. In the extractive industries, for example, issues can arise from the immovability of assets such as mines or reserves, or the occurrence of rent and consequently the generation of super-normal profits. Other issues include the susceptibility of primary commodities to market cycles, severe short-term price volatility and, not least, to the impact of innovation and substitution in changing demand for raw materials offering similar properties.

Robin spent some 25 years with CRU. After an initial period, he left to work for Chase Manhattan Bank (now part of JP Morgan) before establishing his own company in Pennsylvania, Resource Strategies, which CRU acquired in 1995 as part of its expansion in North America.

Robin made his distinctive presence felt across the spectrum of CRU's activities. Initially the focus was on non-ferrous industries such as copper

and aluminium but, by the time Robin re-joined, CRU had expanded its coverage to the steel complex, energy industries and agricultural sectors. As our client base grew so our challenges became more diverse. Robin played a leading role in that expansion process and helped to develop new methodologies that had the breadth of scope and sophistication needed for our new markets. Robin for instance pioneered applying systematic econometric modelling to competition between materials in electricity, transport, construction and packaging markets. He was also instrumental in developing what we called CRU's Compass methodology and applying it to long-term forecasting. Similarly, he was involved in improving the company's risk-adjustment methodologies and its value-based costing system for competitive analysis as between mining operations. Robin also led CRU in developing its value-in-use models for negotiating iron-ore and metallurgical coal off-take agreements between western producers and Chinese counterparties.

He particularly enjoyed applying analytical economics to resolve disputes between parties active in natural resources industries. He would facilitate negotiations by identifying what he called Bargaining Zones to achieve win–win outcomes. Robin would frequently be retained to help resolve fiscal differences between host governments and foreign investors in connection with existing or planned mining and infrastructure developments, the merits of more downstream processing, and on matters relating to transfer pricing.

The book draws on all this work, focussing particularly on the characteristics of primary commodity markets and the political economy of extractive industries. Robin puts great emphasis on the range of talents that a mining company executive needs to be able to deploy if he or she is to deal with the complex issues that mining throws up. These can be geological, metallurgical, management, economic, political, social, environmental, regulatory and financial. He states that mining companies need to be led by Renaissance men and women. There is no doubt that Robin Adams was such a person.

Robin was greatly respected and admired by his colleagues. All who worked with him gained from the experience and benefitted from the thoughtful and considerate way he interacted with others. He is remembered as a person who was generous with his time and enjoyed sharing with others what he knew. He was a great mentor both in the office and when it came to outdoor activities, especially deep-snow skiing which he did frequently and expertly in the mountains near CRU's offices just south of Seattle. CRU's US West Coast offices were located on Whidbey Island next to where Robin and his wife Judith, a writer and poet, chose to

build their home. Theirs was a deep and fulfilled marriage that thrived on the complementary combination of their talents and strengths.

Robin often took it upon himself to act as advisor to parties who had been disadvantaged by contamination or pollution resulting from mining and processing operations. In one such case his clients, mainly bondholders and environmental agencies, had been defrauded into bearing heavy costs which should rightfully have been borne by the shareholders. Only two weeks before he died, in spite of his deteriorating health, Robin made an extraordinary effort to give a deposition which was crucial to the cause he felt so strongly about. (This book concludes with one of Judith's poems, reprinted with her permission, that memorialises Robin's deposition.) As a result of the deposition the shareholders were found guilty and required to pay out over $215 million. They were refused appeal to the US Supreme Court.

To me personally, Robin was a close colleague and greatly valued friend. He was a source of sound and impartial advice and a person I valued for his warmth and integrity as much as for his brilliance. Even today at CRU one of our key steps in resolving analytical problems is to ask: "How would Robin have approached this?"

Well, this book provides some answers.

Robert A. Perlman
Chairman, CRU Group

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Acknowledgements

It is a privilege for me, as Robin's wife, to write this acknowledgment on Robin's behalf. I know Robin was immensely grateful for all the help he received while writing this book. I know that he would wish to thank also those who helped him during his entire career in the field of mineral economics which was, in fact, much wider than the material he covers in this book. He met many interesting people who cared about the industry and the ethics of working in the mining industry.

Robin started to write this book after he received his terminal diagnosis of a period of only a few months. He worked on the text while undergoing treatment and the book was completed the day before he died. The hospice overseeing his care administered Ritalin to enable him to finish. Robin was keen to pass on what he had learned during his career which he told me again and again he found fascinating, rewarding and always interesting. It would have distressed him not to acknowledge all those who helped him get this book to print and, as his wife, I am deeply honored to write this on his behalf.

Robin would first have wished to thank Linda Jennings, his remarkable assistant, who dealt with the management of the office. Linda had inexhaustible patience and exercised a calming effect on Robin who at times felt so strongly about things that he could almost levitate. He would also have particularly wanted to thank Stephanie Ryan, a dear friend of ours, who despite having plenty of her own work to do, sat by his bed during the last days taking dictation on her computer as his voice became weak and less distinct. I am not sure he knew who would take on the Herculean task of editing his book but he would have been both thrilled and relieved that two brilliant colleagues would make sure it was finished and in a publishable form. Thanks then to Christopher Gilbert, who was at Oxford with him, and Christopher Stobart, who worked with Robin for a very long time. This book would not be with us if it were not for them. Most importantly, he would like to thank his long-time friend, also his boss, Robert Perlman, who was so much more than a boss and a colleague but a

true friend. They had an exceptional bond for they both felt deeply about ethics both in the work place and in their lives. They shared a special relationship both at work and as friends. I also know that Robin would like to thank Taylor Shively who came to work for Robin out of graduate school. Robin would bounce his ideas off Taylor and get reliable feedback. He would also have thanked the young people he mentored from time to time. The promise they showed gave him hope for the future of the mining industry. Robin would also thank the liberal community on Whidbey Island who surrounded him with encouragement, accepted his eccentricities and challenged his ideas.

Lastly, I know deeply that he would have thanked me for putting up with his sometimes very late arrival home, his booming voice waking me from sleep when he enthusiastically announced his latest idea and for loving him in the way that I did; his elder daughter, Laura, who challenged every idea he had, and was like him in her debating acuity; his son William who, unlike his father, was less of a student but much more of a party guy, who inherited his father's free spirit and occupies himself in saving lives jumping out of a helicopter on a rescue team; and lastly his younger daughter, Rachel, who taught him about so many things including flamenco dancing, how to handle his emotional Portuguese heritage, and who for a while worked for him. One day Rachel reported to me "Mum, dad is an absolute power house at work. I don't how anyone keeps up with him." Robin was proud of his children especially because they, as Carl Jung once said, "lived their parents' un-lived lives"!

I know I have missed out many people in the industry who influenced him, taught him and who touched him over the years. I know he would have wanted to thank the publishers for taking on his book so that his thoughts did not go unheard into his grave on the hill on Whidbey.

Judith Adams

Praise for Modern Management in the Global Mining Industry:

> 'Robin Adams was one of the great mineral economists of our times. Drawing on his many years as an industry consultant and his strong knowledge of economics and business administration, Robin has, with the help of Christopher Gilbert and Christopher Stobart, given us a book that provides a wealth of information on mineral commodity markets. Anyone striving to understand the behavior of mineral commodity markets and gain an insight into the mining industry should read this book'.

John E. Tilton, Emeritus Professor, Colorado School of Mines, USA

> 'This book is a must read if you are planning a career in the minerals industry. Its author, Robin G Adams, with more than 20 years' experience at CRU, one of the world's most prominent consulting firms in the field, exhibits mastery in disentangling the intricacies of this important industry to the lay reader. Complex issues like metal price formation, measurement of production costs, or the myths of resource depletion are straightened out so as to be accessible even to my grandkids, yet with no loss of realism. I am full of admiration'.

Marian Radetzki, Professor of Economics, Luleå University of Technology, Sweden

> 'Robin understood the mining industry better than most of those working in it. In these pages, he tells, with characteristic clarity and vigour, of his personal journey to uncover the economics of the mining industry, to establish where it differs from other industries, and to develop the intellectual tools required to pinpoint where value can be found and how it can be extracted in an effective and responsible fashion'.

Dr David Humphreys, Former Chief Economist of Rio Tinto and Norilsk Nickel

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1

Introduction

I have spent most of my working life as a mining industry consultant. In this book, I put forward my views on the efficient organisation of the world mining industry. I do this as an industry insider and based on my personal practical experience. The views I express are therefore likely to differ from those of academic industrial economists who will view the mining industry from a theoretical or policy perspective.

Despite this qualification, my account is informed both by my undergraduate degree in economics and by subsequent reading in business administration. Over the past half century, business administration has succeeded in establishing itself as a recognised academic subject at the world's major universities. It offers a range of techniques and methodologies that are equally applicable to every sector of the economy, ranging from the local convenience store to the world's largest corporation. This body of knowledge has been commercialised by leading management consulting firms who stress that one of their key advantages is their ability to capture business insights obtained in one sector and transfer them to other sectors. To such companies, the development of industry expertise and know-how is something that may be obtained from the client, or acquired by hiring experts with specialist knowledge, or contracted out to third parties as a last resort.

I take a different view. Sound general management, accounting and reporting principles are as important in the mining industry as in other sectors but they will be insufficient. The mining industry presents a number of challenges that require a different approach for the following reasons:

- *Demand volatility*: As was apparent in 2014–2019, the demand for mined commodities is much more volatile over the business cycle than demand in most other sectors of the economy. This is because mined commodities are disproportionately consumed in sectors such as construction, capital investment, and consumer durables

which are dependent on the discretionary spending decisions of businesses and consumers.

- *Long cycles*: Construction of a new mine takes years, sometime more than a decade. Once built, mines typically remain productive for at least 20 years and often longer. Finance for new developments is most easily available in periods in which prices are high and existing mines profitable but the production from these mines will weigh on prices for an enormous time. Under-investment in mining during the 1990s left the industry unprepared for the massive growth in Chinese metals demand from 2004 onwards. Over-investment over that 'super cycle' period resulted in a fall-back in prices. These long cycles complicate investment decisions.

- *Price volatility*: Mineral commodities are homogeneous, or at best only mildly differentiated from one another. Prices are set in global commodity markets and are affected by supply and demand events that take place all over the world, and also by speculative and investment decisions of all kinds. The resulting price volatility adds to the demand volatility, with the result that the industry's revenue stream is far more volatile that of other sectors of the economy.

- *Geographical specificity*: Mining is a captive industry in the sense that it cannot relocate in response to adverse economic or political developments in a host country, as can other industries such as textiles. Mining takes place where metal-bearing ore is found. This means that mines bear exceptionally high exposure to social and political risk, including potential increases in special taxes once a project is up and running;

- *Environmental impact*: Mining has an unavoidable and intrinsically high environmental impact that requires extremely careful management. Careless actions by some mining companies can trigger widespread opposition to mining in all its forms, which in turn contributes to project delays, cost overruns and, in extreme cases, the inability to continue production.

- *Lack of sustainability*. In the final analysis, any mining operation is an unsustainable activity. Although the world is far from running out of resources, each individual mine does have a finite resource base and sooner or later will close. This creates an obvious source of social tension. (Sustainability, in the sense of minimising the impact of mining on the environment, is a separate concept which is correctly given high priority by all responsible mining companies.)

Such factors are individually present in other industries. All are present in oil extraction. What makes mining unique and a book on mineral economics worthwhile is the intensity with which these factors often combine. They have given the mining industry a unique character that powerfully influences business decisions at both a strategic and an operational level. Miners are not a representative cross-section of society and mining companies are not representative of business corporations. Rather, miners are a largely self-selected brotherhood of rugged and self-sufficient individuals capable of living and operating in remote and sometimes hostile environments and contending with job hazards that are simply not present in the mainstream economy. Miners do not respond well to micromanagement or top down direction. Failure to understand the culture of any industry can frustrate implementation of even the most brilliantly conceived programme for strategic change. The need for cultural change in an industry or a company is often a target of performance improvement initiatives. However, it is unlikely that any change programme will succeed unless change agents understand and respect the deep historical reasons for the industry's current culture.

Thus, the development of industry knowledge and an understanding of its culture become the key requirements of the successful manager rather than a detail to be out-sourced. Industry knowledge includes not simply the obvious – understanding how a commodity is produced, where and why it is used, who the major companies in the industry are, and so on – but also what might be called the 'deep history' of the industry so that the mistakes of the past are not repeated unnecessarily.

It is much more difficult to acquire this deep history, in my experience, than simply to acquire generic management consulting skills. An effective mining industry executive needs to become what I choose to call a 'Renaissance Man' and acquire skills from, or at least develop a high comfort level with, many disciplines ranging from the obvious technical ones such as geology, metallurgy and engineering, to economics, finance, sociology, anthropology, politics and communications. For most people this requires many years, if not a lifetime, of experience. By contrast, the latest techniques in business administration can be acquired quite quickly through the many excellent Executive Management programmes offered by the world's business schools.

I have been engaged in providing mining consultancy services for most of my working life, and in recent years with a leading mining consultancy company, CRU International. CRU and similar companies are firmly committed to the development and retention of industry expertise, which, defined in the broadest possible cultural, technical and business terms, is

the core requirement for successful management in the industry. CRU's mission is to help mining industry stakeholders make higher quality and more robust business decisions by deeply understanding and managing the risks involved. Industry expertise is our core asset.

Mining in Perspective

My goal in writing this book is to summarise some of the industry know-how and related analytical techniques that, with the help of colleagues at CRU and other companies, I have managed to acquire and use in 40 years of consulting. I have chosen to do this by providing examples taken largely from a small subset of the 200-odd minerals used by the twenty-first century global economy – coal, iron and steel, aluminium, copper and the fertiliser minerals. These are high-volume mined commodities with the largest environmental, social and political consequences for society. The affairs of the companies that mine them are reasonably transparent. A huge volume of academic studies, technical conference proceedings and business reports about these commodities is also available. Readers who are interested in digging deeper into information that I am necessarily presenting in a highly summarised form can, therefore, readily do so.

Any sampling bias found in this book has to be seen in context. When I became Research Director of CRU International in 1973, my first task was to advise management on the potential diversification of the company's interests. At that time CRU's business was primarily related to market research and price forecasting in the copper industry. However, the company was fielding inquiries about many other commodities and was looking to expand the scope of its business significantly. Unencumbered by any prior knowledge of metals and minerals, I therefore began my analysis with a clean sheet.

My approach at that time was simple and I will follow the same approach in writing this book. I listed as many minerals as I could identify and looked up world mine production and the prevailing market price in order to calculate the global revenues associated with the production of each commodity. This analysis revealed that 75% of the value of the world's non-fuel mineral production was accounted for by just four commodities – gold, iron, copper and aluminium. As an economist, I understood that gold was a currency rather than an industrial commodity. As a transportation expert, I could see that the importance of logistics cost in the overall price made nonsense of the London Metal Exchange

(LME) warehouse delivery business model for iron ore. Consequently, my recommendation was that CRU should diversify into aluminium, which appeared to me to be similar to, and a partial substitute for, copper. I am happy to report that this advice was accepted and that aluminium forecasting and consulting quickly became a core business for the company. (A few years later, the LME also diversified into aluminium, which has become its most valuable contract.)

Table 1.1 shows the results of a similar exercise 40 years later. To provide a complete perspective of mining, I have added coal, which is the world's largest mined product by volume, and I have separately identified steam coal (mainly used in power stations) and metallurgical coal and coke (used mainly to produce steel). Table 1.1 includes all metals and minerals where annual production exceeds $1bn, but excludes gemstones. It shows that in 2015 54% of all mining efforts[1] are related to providing electricity and steel, two absolutely essential building blocks of urban industrial society. Without them, it is inconceivable that the planet could support its 7 billion inhabitants.

Steam coal represents approximately one-third of the value of global mine production. Coal is still by far the dominant fuel for the generation of electricity, and its market share has increased. However, it is also the single largest contributor to carbon emissions. Alternative ways of generating electricity reduce these emissions by half in the case of natural gas and almost entirely in the case of renewable sources of power, both of which are growing strongly. However, despite the most optimistic projections for alternative fuels, the world will need coal in today's quantities (or more) for at least the next 30 years just to keep the lights on, particularly in high population, low income economies such as China and India where power consumption per capita is far below western levels.

A further quarter of the global value of mine production relates to iron ore and metallurgical coal, which are the essential raw materials in the production of steel, the most commonly used material in the modern industrial economy. Indeed, global consumption of steel is approximately 30 times larger than the consumption of aluminium, the second most widely used metal. Steel is widely used in the construction of residential, institutional and industrial buildings of every kind, bridges and highways, railroads and mass transit systems, water and sewerage plants,

[1] I consider that the value of mine production is a reasonable proxy for mining effort, because in the final analysis costs strongly influence price and are a function of effort.

Table 1.1: Value of Global Mine Production, $bn, 2015.

	Annual Production		Price		Revenue	Share (%)	Cumulative (%)
Steam coal	6,087	m tonnes	59	$/tonne	361.0	34.0	34.0
Iron ore	2,078	m tonnes	56	$/tonne	115.5	10.9	44.9
Gold	97.7	m tr oz	1,159	$/tr oz	113.3	10.7	55.5
Copper	19.3	m tonnes	5,502	$/tonne	106.2	10.0	65.5
Metallurgical coal	1,183	m tonnes	83	$/tonne	97.6	9.2	74.7
Aluminium	56.5	m tonnes	1,663	$/tonne	94.0	8.9	83.6
Phosphate rock	258	m tonnes	117	$/tonne	30.2	2.8	86.4
Titanium	5.5	m tonnes	5,023	$/tonne	27.5	2.6	89.0
Zinc	13.2	m tonnes	1,933	$/tonne	25.6	2.4	91.4
Nickel	1.9	m tonnes	11,835	$/tonne	22.4	2.1	93.5
Potash	60.2	m tonnes	228	$/tonne	13.7	1.3	94.8
Silver	874	m tr oz	15.4	$/tr oz	13.5	1.3	96.1
Lead	5.0	m tonnes	1,787	$/tonne	9.0	0.8	96.9
Platinum	5.8	m tr oz	1,054	$/tr oz	6.2	0.6	97.5
Tin	315,000	tonnes	16,084	$/tonne	5.1	0.5	98.0

Uranium	60,500	tonnes	81,153	$/tonne	4.9	0.5	98.5
Palladium	6.5	m tr oz	690	$/tr oz	4.4	0.4	98.9
Molybdenum	287,000	tonnes	14,636	$/tonne	4.2	0.4	99.3
Cobalt	98,100	tonnes	28,920	$/tonne	2.8	0.3	99.5
Magnesium	1.0	m tonnes	2,223	$/tonne	2.2	0.2	99.8
Antimony	147,000	tonnes	7,287	$/tonne	1.1	0.1	99.9
Tungsten	86,100	tonnes	11,884	$/tonne	1.0	0.1	100.0
Others					0.5	0.0	100.0
Total					1,062	100.0	

Source: Author's calculations from CRU data.

power transmission towers, and almost all other forms of infrastructure. Another major use of steel is in the production of machinery and other capital goods that are required for the operation of manufacturing industry. Without steel, there is no urban industrial economy.

A further quarter of the value of production reflects the production of gold, aluminium and copper. Eight other commodities – phosphate rock, titanium, zinc, nickel, potash, silver, lead and platinum – take the cumulative share to 97.5% of total value. For all practical purposes, everything else extracted from the earth's crust can be considered as a niche business. Individually, none of them account for more than 0.5% of world mine production.

Minerals produced and used in small quantities can, of course, be crucial to some manufacturing processes, but at the same time the volume and value of world production may be insignificant compared to the major minerals from which I draw my examples in the body of this book. As an example, it may be helpful to reflect upon the concern expressed in recent years over the potential dominance of China in the supply of rare earth oxides (REOs). In 2014, China is estimated to have produced 95,000 tonnes per year of REOs out of a world total of 111,000 tonnes. These minerals (there are 17 of them) are critically important in automotive pollution control catalysts, permanent magnets and rechargeable batteries. Demand is expected to grow strongly as future global demand for conventional and hybrid automobiles, computers, electronics and portable equipment increases. Expanded rare earths usage is also expected in fibre optics and a wide range of medical equipment applications. In other words, REOs play a crucial role in modern, high-technology growth sectors of the economy.

However, the value of global production of all 17 REOs was just $1.65 bn in total, using 2012 prices. Thus, all REOs collectively represent only 0.1% of the value of world mine production. It is worth adding that REOs are not all that 'rare' either. According to the US Geological Service, world reserves are 1,000 times greater than current production, and only half of them are in China. In other words, a hypothetical Chinese attempt to squeeze international consumers by restricting exports would have only a short-term impact. The resulting price increases would be very likely to stimulate additional supply from other countries, and the absolute size of the investments required for this transformation would be modest when judged in terms of the industry's global financial capacity. To put this in perspective, a single new iron ore mine, the Roy Hill project in Western Australia, which came into production in 2016, is expected to have an

Table 1.2: Value of Production of Extractive Industries, $bn, 2015.

	Production		Price		Revenue	Share
Crude oil	33,460	m bbls	50.8	$/bbl	1,700	52.3%
Natural gas	3,539	bn m^3	0.14	$/cubic m	491	15.1%
Coal	7,270	m tonnes	63.1	unit value	459	14.1%
Non-fuel minerals	2,500	m tonnes	241	unit value	603	18.5%
Total					3,253	

Source: Authors' calculation using data from Table 1.1 and BP: *Statistical Review of World Energy*, June 2016 (oil and natural gas production); IMF: *International Financial Statistics* (oil and natural gas prices).

ultimate capital cost of $14 bn and will have an output worth over $6 bn per year at current prices.

Another perspective can be obtained by comparing the value of non-fuel mineral production with the value of the production of various fuels. From an overall economic perspective, the energy industry is far more important than the mining industry. Non-fuel minerals account for less than 20% of the total value of all extracted minerals whether mined or pumped. Oil accounts for more than 50% as set out in Table 1.2.[2]

Steel-related Minerals

Within the universe of non-fuel minerals, iron ore is clearly the most important mineral because it is the raw material base for the steel industry. A number of other minerals are also tied to the steel industry. These include the bulk ferroalloys such as ferromanganese, ferrosilicon and ferrochrome as well as more specialised alloys such as nickel and molybdenum. The use of alloying materials imparts special properties to carbon, alloy and stainless steels, including resistance to rust, improvements in ductility and strength, resistance to chemical and environmental corrosion and so forth. When these additional materials are taken into account, as much as 40% of the value of the global metals and mining industry's output must be considered as steel-related.

[2] Calculated using average crude oil price and average of United States and Russian natural gas prices.

From a business perspective, a key economic issue is that iron ore has a low value to weight ratio and is required in enormous quantities. The management challenge is therefore as much about logistics as it is about mining and beneficiation. Similar challenges arise with other so-called bulk commodities such as the bulk ferroalloys, bauxite and phosphate rock. Another feature of these bulk commodities is that quality varies from one producer to the next, which introduces significant complications in any analysis of markets, prices and competition.

Power-intensive Industries

The next most important commodity in the industrial economy is aluminium. Its main uses are in the construction, transportation and packaging sectors. A key driver of aluminium demand is its very light weight, which makes it an ideal material for transportation equipment, as reduction in the weight of vehicles is a key to improving fuel economy. Aluminium is now making significant inroads into the previously dominant position of steel in the automobile industry as vehicle manufacturers strive to meet government-imposed fuel economy standards without sacrificing the interior size of their vehicles or the amenities they offer. Another strategic advantage enjoyed by aluminium is the plentiful nature of bauxite, the main source of raw material. Aluminium is the third most common element in the earth's crust after oxygen and silicon. While it is very energy-intensive to smelt aluminium in the first place, once in service the material can be recycled far more easily than any other metal with a small fraction of the energy required for its initial production.

From a business perspective, aluminium really involves two commodities, one a mineral and the other energy. The extraction of bauxite, aluminium's raw material, is an example of (usually quite simple) bulk commodity mining. However, bauxite mining represents only 5–7% of the total value of primary aluminium. Bauxite must first be converted into alumina in a chemical process plant, at which point the alumina represents 25–30% of the value of aluminium metal. The alumina must then be reduced to pure aluminium in an electrolytic smelter, which requires huge quantities of electricity. Thus, aluminium smelters tend to be located in places where relatively cheap power is available. The insights obtained from a study of aluminium can readily be transferrable to other power-intensive industries such as silicon and magnesium.

Hard Rock Mining

Another metal of critical importance is copper, the world's pre-eminent conductor material. Approximately 70% of copper ends up in wire and cable products that facilitate the distribution and use of electricity and support communications networks. Aluminium is an alternative conductor material and is widely used in high voltage overhead transmission cables. However, copper remains the preferred material for most electronic products and major electrical appliances, as well as for wiring inside buildings. Without copper, the world would revert to the pre-electricity age and would not be able to support current population levels at anything resembling today's standard of living.

Despite periods of temporary surplus, resource scarcity is the key business issue in the copper sector. Resource scarcity may be a reflection of the absolute scarcity of the mineral within the earth's crust, or it may reflect the fact that the mineral has been mined for many centuries, and consequently all the very high grade deposits have already been exhausted. Copper is an example of the latter. Copper ores currently being extracted grade at about 1%, compared to grades of 5–10% that may have been mined in past centuries, and typical grades of 30–65% for iron ore, 30–50% for bauxite and 10–30% for phosphate rock, all of which occur naturally in much greater quantities.

This means that the key challenges in copper are related to the mining process, which are now locating, extracting and beneficiating extremely low-grade ores in increasingly remote locations. Economic considerations in copper are therefore similar to those encountered in other relatively scarce minerals such as cobalt, nickel, molybdenum and, arguably, lead and zinc. This group of metals is sometimes known as the 'base metals'. The term 'hard rock mining' has also been used to describe the extractive process in these sectors, and to differentiate them from bulk commodities such as bauxite discussed above. Most of these metals are smelted and refined to virtually pure standardised forms and many of them trade on organised commodity exchanges.

Fertilizer Building Blocks

The final group of minerals discussed here are phosphate rock and potash, which are essential to the world's food supply. Advances in agricultural yields have made it possible to feed a global population in excess of 7 billion people. In turn, the application of nitrogen (N), phosphorus (P)

and potash (K) fertilisers has been one of several factors that have made this possible.

The world obtains most of its nitrogen from the essentially limitless supply in the earth's atmosphere. The key input is not the raw material itself but the energy (usually in the form of natural gas) required to convert atmospheric nitrogen into ammonia, the basic building block of nitrogen fertilisers. The P and K components of fertiliser come from mined products. In the absence of these fertilisers, agricultural yields would almost certainly decline, even if natural fertilisers were a partial replacement. Although we might be able to mitigate part of this in various ways, one result would almost certainly be higher food prices and probably widespread hunger in some countries. Another outcome might be to require that even more land be converted for agricultural use.[3]

This sector raises business issues similar to those found in other parts of the mining industry, but it also has to contend with a far more complex set of marketing issues in an economic sector that is becoming increasingly exposed to critical review from an environmental and health perspective, while still being expected to supply cities with extremely cheap food. Fluctuating crop prices and a bewildering array of governmental support, taxes and regulation leave farmers exposed to potentially unstable incomes, which obviously affect their capacity to invest in the subsequent growing season. On top of this, the optimal fertilisation is a complex function of the kind of crop planted, the soil type and the equipment available. Effectively, the fertiliser sector presents affordability and substitution issues in a manner that is far more intense than for metals.

I have not drawn many examples or anecdotes from the other group of economically significant minerals, the precious metals. By far the most important is gold, the vast majority of which is used as an investment product. As a result, at least 90% of all the gold ever mined is still available in above-ground stocks. There are some industrial uses of gold in the electronics and dentistry sectors, but these require small quantities compared with annual mined production. The main consumer use of gold and other precious metals is in jewellery and other decorative objects. Substitutes are readily available for gold's industrial and consumer uses.

While the mining of commodities such as iron, bauxite, copper, phosphates and potash is clearly fundamental to the living standards

[3] Agriculture has a far greater impact on the environment than any other industrial activity. For example, the conversion of native forest into arable land has been identified as a key factor in the increase of carbon emissions and the reduction of biodiversity.

of the world in which we live, the same cannot be said of gold. There are many alternatives to luxury consumer products that contain gold. Moreover, it is hard to make the case that mankind is achieving a great deal by digging up gold in places such as Africa and Latin America and then burying it in bank vaults in Dubai, London, New York or Zurich so that it can be used as backing for investment products. Finally, gold no longer plays any real role in the international monetary system. The famous British economist, John Maynard Keynes, has been credited with describing the gold standard as a 'barbarous relic'.[4] It is a sentiment with which I concur as much today as when I first encountered the proposition at university.

However, the other precious metals do have significant industrial uses. Over half of all silver usage is in industrial applications. More importantly, platinum catalysts have allowed auto manufacturers greatly to reduce the pollution emitted by vehicle exhaust systems. They are thus instrumental in reducing the adverse environmental impact of vehicle use.

Identifying the Core Issues

While the emerging 'Renaissance Man' will face a wide range of issues, I have tried to identify those issues of most importance and those with which most mining company personnel feel least comfortable. First and foremost is price, which is extremely volatile from one day to the next. The trend seems to be down more often than up and engenders a sense of helplessness. Price appears utterly outside the influence of management, whether by producer or consumer. This uncertainty permeates almost every action in a mining company from the nature of the dialogue with shareholders and financial institutions at the top of the company to borderline obsessive micromanagement of supplies in the maintenance department of a mine.

For this reason, the first section of this book is an attempt to de-mystify the fundamental problem of commodity price risk. Understanding why markets produce certain prices is the starting point for forecasting prices. This leads naturally to a discussion of what is involved in commodity marketing and the role of commodity exchanges, and ultimately a discussion of managing price risk, once it has been quantified and its materiality has been determined. If we can then understand commodity

[4] Keynes, J.M. (2003). *A Tract on Monetary Reform*. London: Macmillan.

prices and to some extent forecast them, we can at least plan in a meaningful way. Mining companies can also earn marketing and trading premiums, and in many instances at least partially manage price risk. Improving a company's comfort level on price will reduce the feeling of helplessness and open the door to other initiatives for taking control of its destiny.

The second section of this book directly addresses what I think is the single greatest cultural obstacle to more effective management in mining, namely that the only viable business strategy in a commodity sector is to build or acquire low-cost operations in the first or maybe second quartiles of the supply curve. This thinking stems from the cultural impact of price uncertainty. Managers know they cannot do anything about price but think they can do something about costs. They think getting costs down means not only earning a higher profit margin over the cycle but, more to the point, improving job security in a high-paying, but also high risk, occupation. I try to correct this bias by showing how it is at odds with modern concepts of business strategy. I discuss the basics of value-based management that many mining companies say they have adopted. I introduce a number of techniques developed by CRU to allow companies to reorient themselves from a narrow technical focus on cost of production to a broader focus of delivering value. I also discuss more specific techniques such as benchmarking and out-sourcing, and the pitfalls involved.

The third section of this book addresses mine development, the life blood of the industry. This is where the demands on the 'Renaissance Man' combine in their most intense form and where there is still major unfinished business in the relationship between the industry and the societies and environments in which companies operate. I cover the rewards and pitfalls of the mine development process, because we need new mines, not simply to meet growth in demand for commodities but also to replace mines that have depleted their resource base. The capital investments involved are very large, the decision-making process is complex and extended over long periods of time, and exposure to risk is typically at its most acute at this point. Moreover, this is where the industry has its most immediate impact on the environmental, social, and political health of the societies that provide these resources for the benefit of the rest of the world.

This book is not intended to supply answers. It is intended to improve the reader's comfort level with the three most important topics in mining – dealing with commodity price risk, maintaining a competitive position and effectively managing the mine development process. If readers come

away with the notion that there are often more dimensions to a problem than meets the eye and that most of them require a multidisciplinary approach for their solution, I will have at least made some small contribution to improving the quality of business decisions. If I stimulate even one person to decide that he is going to become a 'Renaissance Man' and lead a mining company from this perspective, the time I have spent writing this book will have been justified.