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Mineral Beneficiation in Africa: what was missed and what can now be done?

Abstract

To the extent that value-addition to minerals is only achievable by a well-trained and fully equipped labour force (technicians, technologists, engineers, designers, entrepreneurs, etc.), through enabling institutions and networks, the human resource development factor lies at the heart of mineral beneficiation. Does Africa have this capacity? The question of capacity was the most significant, and least disputed, finding of MISTRA's "Use and Displacement of Hydrogen Fuel Cells" research. The readiness of the continent and a country to effectively beneficiate mineral resources is dependent on the availability of appropriate human capital, competitiveness and an enabling policy environment. Mineral beneficiation is practised mainly out of resource-rich countries and contributes to sustainable job creation, social development and economic growth (i.e. China, the US, Australia, etc.). Africa's resource rich countries, if focusing on beneficiation as an avenue to improve economic growth might extend the returns from mining activity to a broader segment of their home population. This relies on significant increases in mineral processing skills, supporting policy development, and the investment in infrastructure. This paper studies mineral beneficiation in African resource-rich countries aiming at providing recommendations for countries to better beneficiate available mineral resources, to create an even better sustainable development within the countries and their surroundings.

Introduction

Africa is rich in resources, but the yields from these resources have led to limited development of the local population. With foreign manufacturing and mining companies investing and trading with the continent mainly for its rich natural resources, sustainable development and job creation plans have been put in place particularly in the mineral resource-rich countries of the continent to enable economic growth within Africa. Some South African examples are the NDP, Motor Industry Development Plan as well as NEPAD in the broader African continent. Beneficiation has been a component of plans to develop the African continent given the wealth of the continents mineral resources which ranges from diamonds, gold, uranium, bauxite, steel, aluminium, copper, platinum, coal, etc. Beneficiation started to take shape in countries like South Africa, Botswana and Mozambique, after mining in these countries changed from being a predominantly primary commodity exporter, to being the exporter of processed minerals, in the 20th century. Changes in political regime led to changes in the role of beneficiation. Beneficiating minerals in the present era ranges from building of road infrastructure, manufacturing, and developing of harbours for better shipping of minerals out of the continent. South Africa is seeing more heightened development since most minerals discovered in the country are mostly of strategic use to the world. Nonetheless,

unlike in the ancient times beneficiating minerals today requires the services of well trained and fully equipped labour together with enabling institutions and networks. These resources will enable market competing production of goods that can be sold internationally. The question now is, with the minerals still underground how can Africa ensure increased beneficiation to create better sustainable jobs and economic growth for the continent? For its developmental purposes Africa has the ability to grow its economy by strategically applying comparative advantage theory and implementing innovative ideas ensuring economic growth through thorough knowledge of its natural resources. Resource curse and corrupt leadership are also some factors hindering growth in Africa however, the continent has growth potential. This paper serves to address and interrogate, through a wide scale reading of available literature, the seeming inability of the African continent to beneficiate its mineral resources using South Africa and China's economic growth as the study case.

1. Beneficiating minerals (history)

The term 'mineral beneficiation' is generally defined as a value adding process on minerals from extraction to refining to production of the final consumable good. The history of mineral beneficiation goes to as back as in the 10th century when minerals were discovered and were at times used as a medium of exchange before the introduction of money (Oracle Think Quest, 2011). Beneficiating minerals and trading them for money started arguably in the 14th century using the method "Hand Sorting" to pick up the valuable pieces of ore from the gangue, this method together with the gold "Washing" method where the ancient Egyptians' methods of beneficiating minerals. However, methods such as "Crushing (hand, pounding, lever crush, bouncing, water wheel), Gold Panning and grinding ore with a grindstone were the first steps in beneficiating minerals also used until the mid-20th century when better technology was developed. This lead to the opening of schools of mines meant to teach mining and metallurgy, geology and mineralogy. At this stage only a few professors had sufficient knowledge about mining and Peter von Rittinger of Schemnitz School of Mines in Austrian Empire was one of them. He taught mineral dressing and wrote specialized books on mining and minerals. These was followed by opening of institutions in North America, London and Columbia where subjects of interest were mineral beneficiation, chemical engineering, geology, metallurgy and other courses leading to maximizing beneficiation. During this era the importance of trading was to maximize mineral beneficiation and sustained development therefore road infrastructures, buildings, manufacturing industries and harbours were developed for better trading of minerals between countries (Istanbul, 2006).

Today beneficiation is broken down into four stages with the commodity gaining value as it moves from one stage to the other as illustrated in figure 1 of the appendix, they are;

- First is the extraction of raw ore and turning it into a highly concentrated product.
- Secondly, production of metal alloys, the first process of manufacturing.
- The third stage is a crucial one were various skills are applied enhancing the mineral to meet the requirements of the end user.
- Lastly, is the selling and consumption stage were the final product is reached and ready to hit the market.

Due to production and labour costs involved in turning the raw ore into the final product i.e. jewellery, the mineral is now more valuable than at its initial stage (Abedian, 2013).

However, labour and capital required in the first two stages of beneficiation are more or less the same as required in the last two hence the stages can be clustered into two groups, the 1st being mining and the 2nd being manufacturing as shown in figure 2 of the appendix. From the discovery of minerals in ancient times it has been the quest of the founders to study, understand and process these minerals in order to beneficiate (Baxter, 2012). Moreover, beneficiating minerals can take two forms, firstly "the downstream" and then the "side'-stream" both crucial for job creation, economic growth and social development. The downstream beneficiation described as the core beneficiation form where an iron ore is extracted, processed and a final product is reached and distributed. The side-stream however is what one could refer to as rather an extended form of beneficiation. This could be building infrastructures, roads, harbours, airports, railways, institutions and so on reason being the need to process the minerals, distributing them to different destinations and then selling to clients/customers.
Beneficiation is in this paper defined as the ability of a continent to extract, refine, process and produce final product using the skills and capital developed within the continent. Capitalizing on the availability of these resources to develop and provide sustainable job creation for better social development for the continent.

2. African strategic mineral resources and their importance to the world

Africa has quite a number of mineral resources whose downstream and side-stream beneficiation is crucial for sustainable job creation and development in the continent. Bearing in mind that mineral beneficiation is broad and can take different forms, strategic minerals in Africa include:

- ***Gold*** – believed to be mined from as long as 2000 BC by the Egyptians, gold is one of the minerals found in larger quantities on the African soil with the

current world production at about 2400t a year (Mineral Resources H2, 2009). Gold has been revered in almost all human cultures and also used to measure human wealth. This glossy shiny precious metal is extremely malleable, conducts electricity, doesn't tarnish, alloys well with other metals and is easy to work into wire or sheets. Its applications include; jewellery, electronics and computers, dentistry and medicine, medals and awards and also in the aerospace industries not forgetting that gold is a monetary asset in finance and investments and a store of value used to hedge against inflation. This makes gold an important metal for use all over the world (Scottsdale Bullion and Coin, 2014; Mineral ResourcesH2, 2009*).* Figure 3 in the appendix illustrates the gold value addition cycle.

- ***Diamond*** – this hardest known natural substance, naturally-occurring mineral composed of carbon, is a chemically resistant mineral suspected to be formed "at high temperatures and pressures that occur in the Earth's mantle" are mostly found in Congo, Angola, Botswana, Australia, Russia, South Africa and Canada. Diamonds are used in the jewellery, manufacturing industries, in laboratories and also for mechanical parts as a cutting tool in almost every manufacturing industry (Oracle Think Quest, 2011)

- ***Platinum group metals*** – As far as pollution is a concern all over the globe, PGMs play an important in the motor industry for the production of catalytic convertors used to control vehicle pollution, chemical catalyst and coatings, dental alloys, electronic components and computer hard disks, jewellery and fuel cells for power generation. PGMs also assume an important role in the production of medicines and petroleum catalysts for gasoline refining, glassmaking equipment and investment coinage. With over 85% of PGMs reserves currently held in South Africa, the demand for the PGMs is mostly by countries outside the continent than it is internally with Europe, North America, Japan and China leading the list respectively (see figure 5 in appendix). For their use, PGMs are said to be 'too precious for fuel cells" resulting in a proposal of military interventions by some in order to ensure security supply (MISTRA, *2013*)

- ***Iron ore*** – the importance of iron differ from one use to the other. In biology, iron is required by the human body for the execution of various metabolic processes. However, in the economy iron is crucial from the production of steel to the building of structures. 27 different types of steel are formed by a combination of iron and other elements like, carbon, chromium, nickel, silicon and so on. Steel place a crucial role in almost all industries, from building to manufacturing even in households and has been on demand given the developments that has been

taking place worldwide. This is one mineral resource that is of utmost important to the African continent given the need for infrastructure development and could easily result in sustainable job creation and social development. Whilst 2% of iron ore is used in metallurgy products, magnets, high-frequency cores, auto parts and catalyst, 98% of iron ore is used in the production of steel. This being the greatest invention and most used material ever (Adam, 2013).

- ***Coal*** – Known as the primary source of energy for heat and electricity, coal in the United States accounts for about 50% of the electricity production. There are however different types of coals each with its unique use, with bituminous coal also used to produce coke, making steel and other industrial process heating with a higher heating than that of lignite and Subbituminous. Other coals are, Lignite which is considered immature because of its softness and has the lowest heating value of four types of coal used to generate electricity. Then there is subbituminous coal, a dull black coal with higher heating value than Lignite also used for electricity and heat spacing. And lastly, the "hard coal" Anthracite formed from bituminous coal under increased pressures in rock strata during the creation of mountain ranges. Being the most compact of them all, the Anthracite coal has the highest energy content of the four levels of coal (TEEIC, 2013).

- ***Crude oil*** **–** Being the most influential factor in pricing and inflation worldwide and its importance to our daily lives makes it one of the worlds' treasured minerals energy resources. Now, defined as "the raw form of oil that is found in certain formations of rock on earth and on oil sand", crude oil is a carbohydrate which at times contains sulphur and oxygen and is at most found on a sea bed and similar places.

When processed and refined, crude oil has all values and is versatile and its uses include more than 300 petrochemical products. However it is basically used for medicine purposes, boat waterproofing, gasoline products, liquefied petroleum gas, diesel, alpha salt, residual fuel oil with most of its fuel products used to run automobiles and other engines and machines, hence crude oil is the most influential resource on pricing and inflation worldwide. Well some well-known uses of oil include its importance in the kitchen and its presence in most body lotions we put on ourselves. The USA, China, Japan and India are said to be the biggest world oil consuming countries in the world (no wonder the economies are one of the worlds' best) with Africa producing 10.9% in 2012 and North America, South and Central America, the Europe and Eurasia, the Middle East and Asia Pacific producing 17.5%, 9.2%, 20.3%, 32.5%, and 9.6% respectively (BP, June 2013).

With the abovementioned minerals not being the only minerals available on the African soil, there is Zinc, Lead, Uranium, Phosphate, manganese and Copper which plays an important role in almost all aspects of manufacturing, production and transport.

3. South Africa and mineral beneficiation

Studies show (STATSSA, 2013*)* that South Africa is arguably one of the richest countries in terms mineral resources in the world, hence it is used as a case study in this paper. South Africa is one of the countries in the world where mineral resources such as gold, diamond, platinum, coal, copper and iron ore were discovered in large quantities in the past. The discovery of these and other minerals in the country has led to major developments in road infrastructure, buildings, manufacturing and transport services. Although mineral deposits were discovered in the country from as early as in the 10th century beneficiation in the country started to take shape in the 1900s due to the improvement in the political climate of the country leasing to the mining industry from being just a predominantly primary commodity exporter to the exporter of processed minerals (SIMS, 2012*)*. The changes led to the development of today's well known cities like Johannesburg, Pretoria, Cape Town and Kimberly as economic activities in these towns improved. Despite experiencing dramatic economic growth in the 1990s, the country's mineral accounts has been on a decrease and beneficiating minerals has since been on a decrease and today South Africa is faced with challenge of beneficiating its minerals (SIMS,2012*;* STATSSA, 2013*)*. In his 'mineral beneficiation' presentation, Dr. Iraj Abedian graphically illustrated beneficiation stages in which he also indicates the value adding stages that take place out of the resource rich countries (see figure 1 in appendix). This stage of beneficiation is referred to as a capital intensive stage whereas the rest of the stages which are said to be labour intensive are outside resource rich countries. This could be creating jobs, growing economy of the countries in question and development of their states resulting from beneficiating minerals from the resource-rich nations.

The discovery of minerals in a country draws attention of foreign investors to the country and when an agreement is reached it leads to developments. Together with development comes with the GDP growth and better international trade between the country and other countries mainly the developed ones. In South Africa the mining industry is one of the most developed industrial clusters with extensive science and technology network/research, broad expertise in geoscience, large number suppliers of equipment and services and sophisticated financial services (Baxter, 2012). Beneficiation seen as possible growth curve for the country's economy, there are several strategies put in place by the South African government in order to maximise mineral beneficiation in the country. These include the Industrial Policy Action Plan (IPAP5) strategy developed by Department of Mineral Resources (DMR), the Motor Industry Development Plan

(MIDP), the National Development Plan (NDP), IRP2010 and the New Growth Path (NGP). These strategies together are meant to help the country maintain a sustainable economic growth leading to better job opportunities in the country.

4. **Mineral beneficiation one of the reasons leading to China's "booming economy"**

It was in 1978 when the Chinese government embarked on a major program of economic reform which has resulted in the annual economic growth of over 9 percent whilst the pre – 1978 growth was at 6%. The Chinese economic growth is such that the country's economy is predicted to become greater than that of the United States in about 20 years' time (International Monetary Fund, 1997). Amongst other factors leading to China's economic growth is the "policy on mineral resources" (IMF, 1997). However 40 percent of the growth was during the period 1990-1994 as China diverted from the traditional view of development to the modern ways of development, at this period the country's productivity level increase from 1.1 to 3.9 percent. This was made possible by the introduction of profit incentives to rural collective enterprises owned by local government, family farms, small private businesses, foreign investors and traders. Unlike Africa, the Chinese government had control of many industries and thus making it easier for the country and its leaders to work together towards one ideological goal on beneficiating minerals leading to the country's growth (International Monetary Fund, 1997).

In China's Policy on Mineral Resources (Xinhua net, 2003), the country attaches great importance to sustain development and the rational utilization of mineral resources. China made sustainable development a national strategy and the protection of resources an important part of this strategy. Secondly, it was to build a well-off society in all-round way in the first 20 years of the new century. Then thirdly, was that China will depend mainly on the exploitation of its own mineral resources to guarantee the needs of its own modernization program. To increase its domestic capability of mineral resources supply, Chinese government encourages the exploration and exploitation of the resources in the market demand, especially the dominant resources in the western regions. And most importantly, it is an important policy to import foreign capital and technology to exploit the country's mineral resources and help local enterprises and mineral products enter the foreign mineral international market (International Monetary Fund, 1997; News Xinhua net, 2003).

China is also one of the countries in which beneficiation is practiced to the final stage where a product is ready to be sold to the consumer. The same is the case with countries like, India and Turkey whose growth is mainly due the ability to beneficiate and specializing in that which they can do better. As shown in figure 6 and 7 in the

appendix, cutting and production of the final product is mainly in China, India, Turkey and Italy. However, China's economy has experienced a higher growth than the others and if figure 6 is anything to go by, China produces and manufactures the final product in Gold and other mineral resources. Manufacturing alone contributed just above 35% In China, 34% in South Korea and 31% in Malaysia whilst the contribution was 17.6% for South Africa in the early 2000s,see figure 8 and 9 (Roger Baxter, 2005).

5. Enabling institutions vs enabling networks

Figures 6 and 7 of the appendix indicate several levels of value addition processes that are undergone by the minerals before a final product is reached and sold. Now, for a mineral to go through these processes requires the skills of a well-trained labour force with all the required knowledge about the resources. However, this also requires innovative thinking and application accompanied by the relevant support needed to achieve the success one would be hoping for. It is thus crucial for a country to invest in the skills of its citizens in order to promote efficient use of its natural resources by beneficiating minerals. The production of well-qualified labour force and management to work underground, processing and manufacturing and by researching and suggesting new development strategies can work together in a plan to develop Africa by efficiently using African resources for African development (Mineral resources, 2009). Now, if Africa takes the opportunity to maximize beneficiation especially at these stages by firstly identifying the skills that are needed and not yet available within its labour force and invest in the production of those particular skills through institutions and enabling networks followed by importing skills from countries that are currently beneficiating. The ideology behind institutions like FET colleges, technikons and research centres has since been lost owing to the increasing preference of academic professions. This also has an impact on the production of practically skilled labour force and proper implementation of new development strategies within African countries by different institutions. Processing mineral and other natural resources requires practical skills than theory, first-hand experience can only be gained through FET colleges and technikons. It is of importance to promote university education but it is equally important to recognise and promote the importance of FET's. If we ignore the importance of enabling institutions and networks we could end up like the Asian countries where millions of qualified professionals find themselves doing farm labour a road already in construction in Africa.

6. Suggestions and conclusion

A resource-rich continent does not in any form imply a rich economy. The success of an economy is measured by, supply, demand and efficiency factors. Strategic application of knowledge and skills on the resources to create a sustainable growth and development is without doubt the key. A country's ability to grow is dependent on its ability to compete in the market with the use of its strategic natural resources else its resources will be used to benefit nations that have the ability and knowledge about the resources. Given knowledge skills about these minerals, Africa is set to gain substantial growth and economic development provided the resources use is directed to the development of the continent.

Lessons learned from China are that a country needs to be committed to its ideological goal and have a policy that protects its mineral resources. A country must identify a gap in the market through which there could be a breakthrough for its product. Most importantly is the functioning relationship between the private and state-owned enterprises as a way of promoting skills development and job creation. China also knew that to build a sustainable economy with major development one has to invest in the human capital by importing skills from other countries and the government also allowing exploration and exploitation of mineral resources. At the time the Chinese started working towards development most industries were state-owned and that could be a challenge in Africa where most businesses are owned by the private sector and overseas and foreign investors.

Africa is a resource rich continent with the ability to create a sustainable economic growth, jobs and development for all who live in it. With South Africa and the Republic of Congo ranked some of the richest countries worldwide in terms of mineral resources with Platinum, Iron Ore, gold, diamond and Coal successfully mined every year in large quantities the continent has what it takes to undertake major infrastructural, industrial and economic development and given the strong financial sector of South Africa. With the institutions and networks available within and in neighbouring countries, the continent should invest in equipping the workforce with the required skills and knowledge on beneficiating minerals and create better developmental opportunities within the continent for the continent by its citizens. Furthermore, given the need for infrastructural development (roads, ports, buildings, and factories) and the availability of iron ore, crude oil, gold and platinum in the continent, trading for infrastructural and economic development within its countries should be of importance to the decision makers and strategic thinkers of the continent.

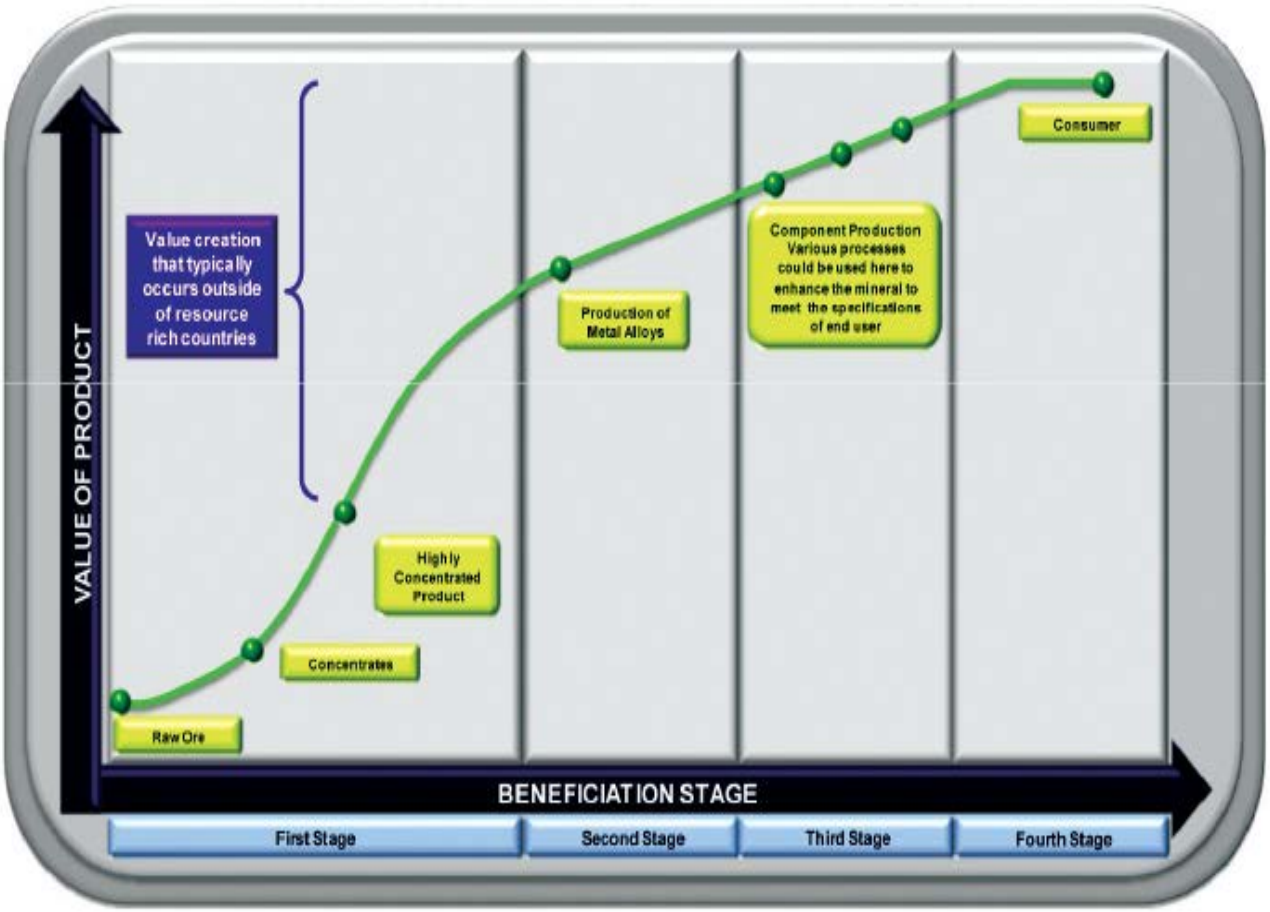
Recent violence and in-wars in other resource rich countries of Africa is also a hindering factor as capital is now moved from development and growth to recovery and rebuilding of destroyed infrastructures. Resource curse is also another growth obstacle Africa is facing. This becomes a challenge given that most investors are foreign therefore only interested in mining and making profit. However development of Africa requires mostly the use of the final products from these resources. It

therefore is the responsibility of the continent to ensure that produce from the mines are then strategically used to develop the continent. Exporting a raw mineral and then importing a final product is boycotting possible growth and development in the process. In fighting resource curse, we are also fighting corrupt political leaders in growth and development. Politics of the continent plays a role on the direction of development.

Now, with the contribution manufacturing has in todays' emerging economies in figures 6, 7, 8 and 9, one can also assume that should Africa utilise its mineral resources to beneficiate there will be more success than there currently is. The thought of what is going to hold the African economy should the mineral resources be depleted, must be sufficient enough for the decision makers in the continent to start investing heavily on skills and knowledge development. This will come handy in times when the need to import raw minerals and manufacture market competing goods arises. African political parties and leaders should altogether work on one ideological goal of development. It is time for Africa to invest in innovative ideas born off its soil and use the natural resources to beneficiate the continent and the future generations.

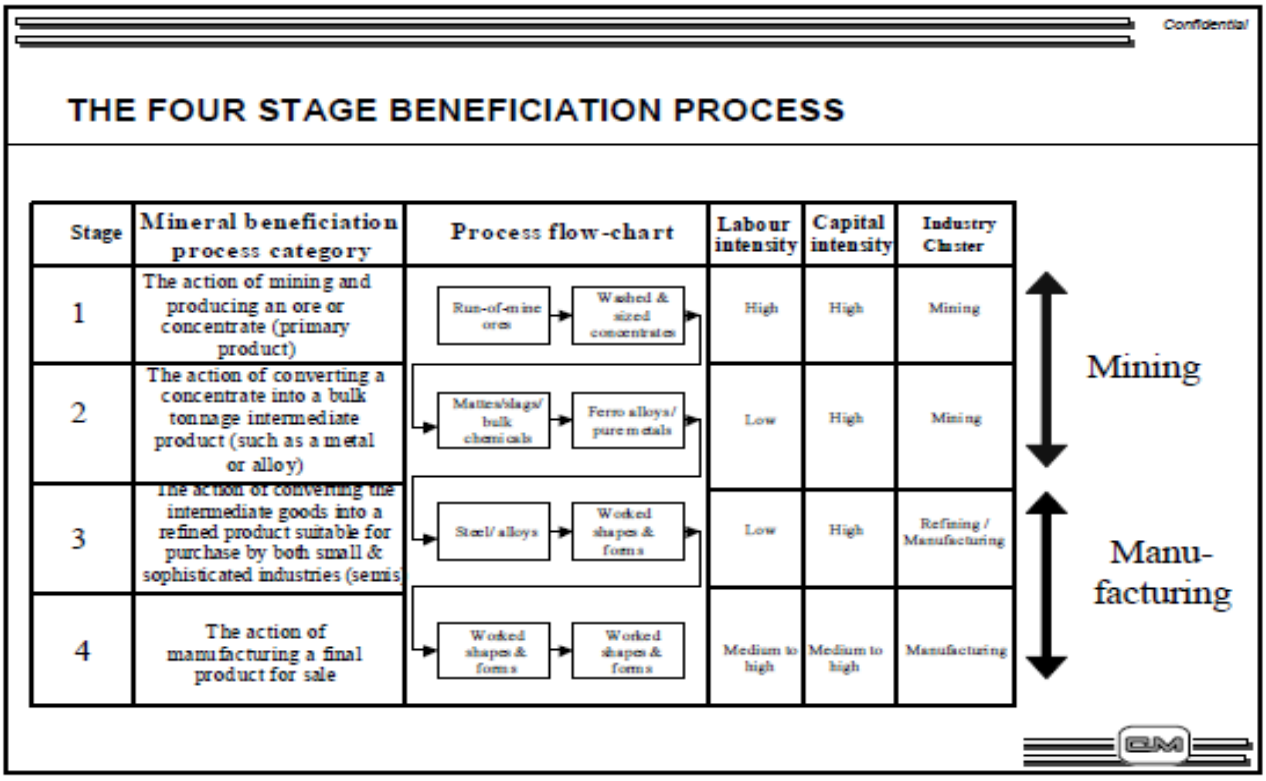
7. Appendix

Figure 1: mineral beneficiation stages



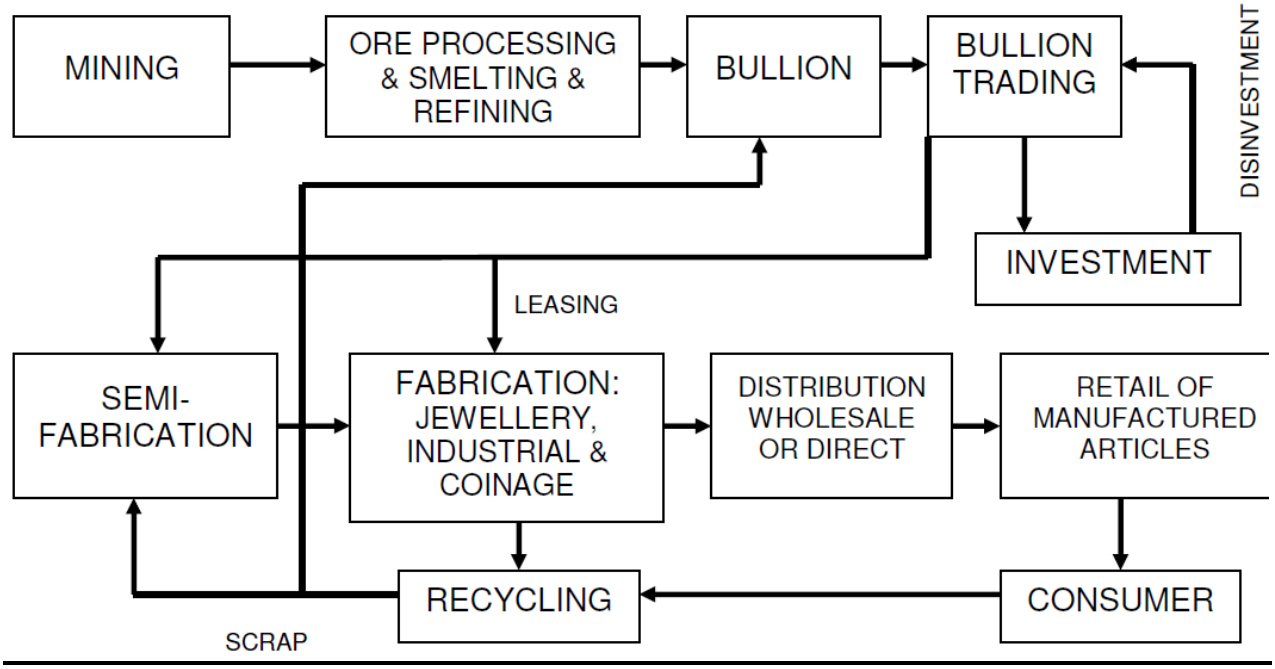
Source: PAIRS

Figure 2: stages of beneficiation as per Baxter's presentation



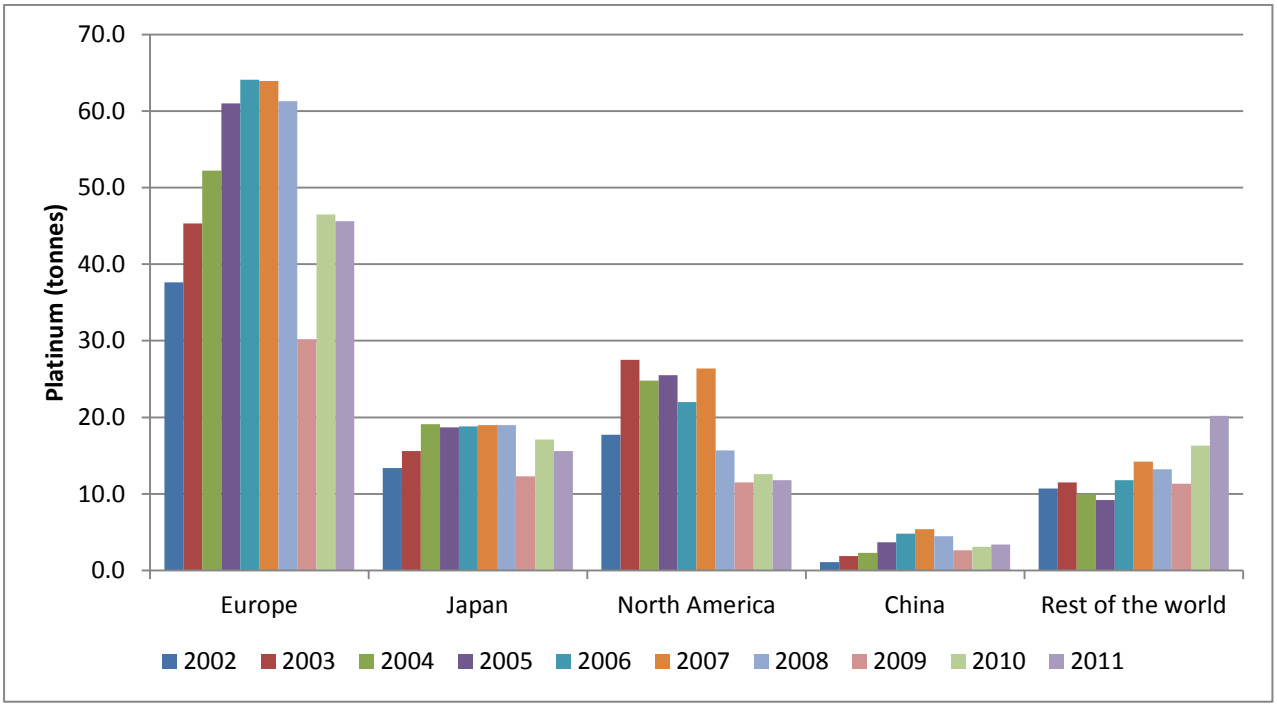
Source: Chamber of Mines South Africa

Figure 3: Gold value adding cycle



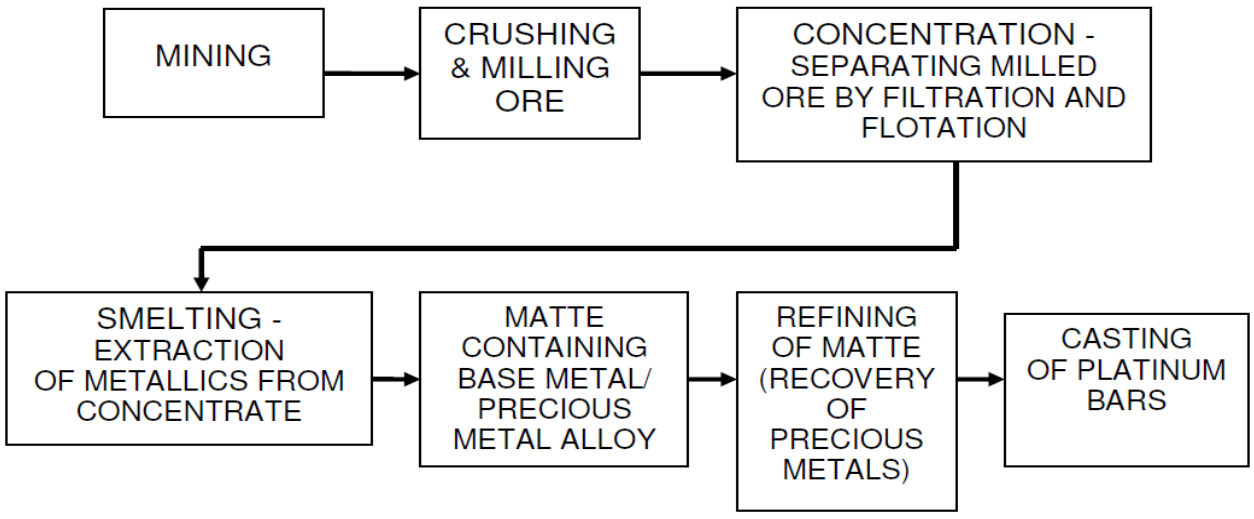
Source: Mineral Resource South Africa

Figure 4: Platinum auto catalyst demand in the world



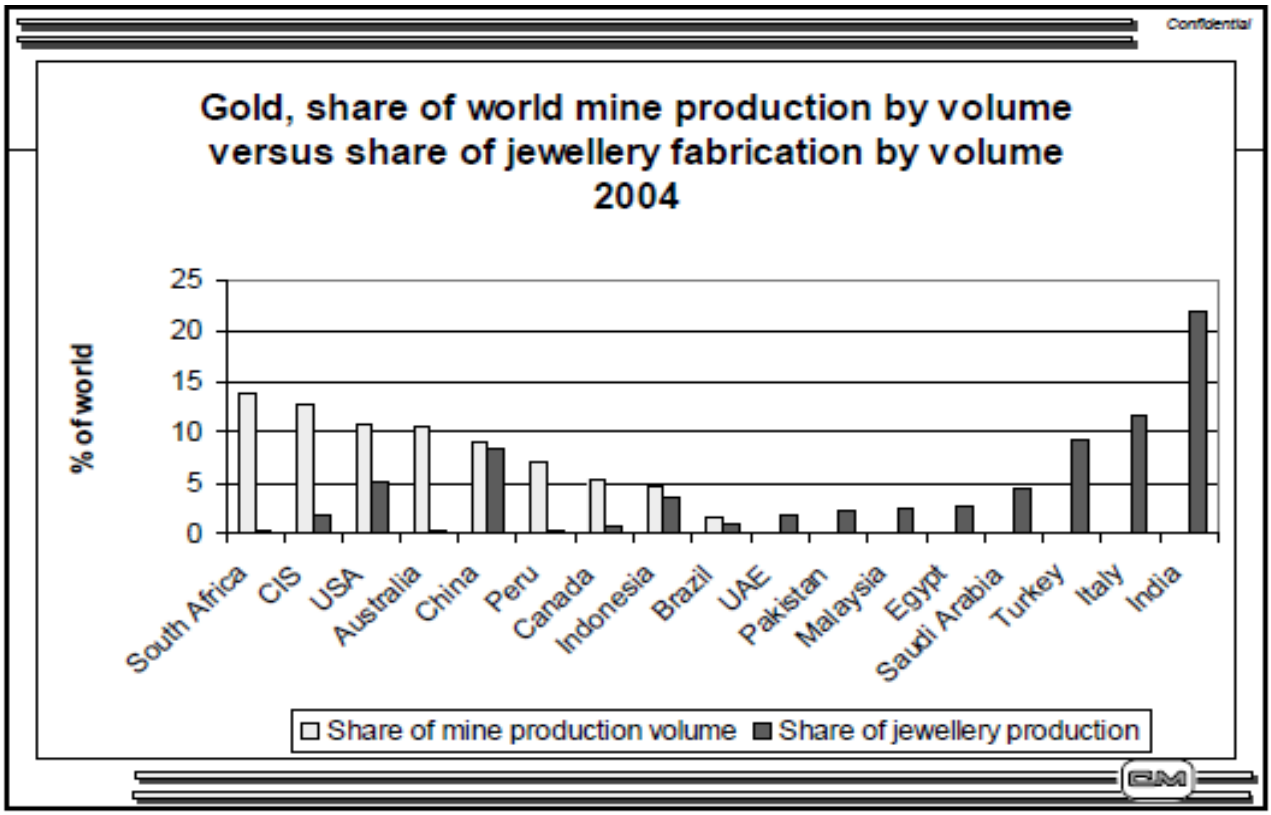
Source: Johnson Matthey Plc, 2013

Figure 5: Platinum value adding cycle



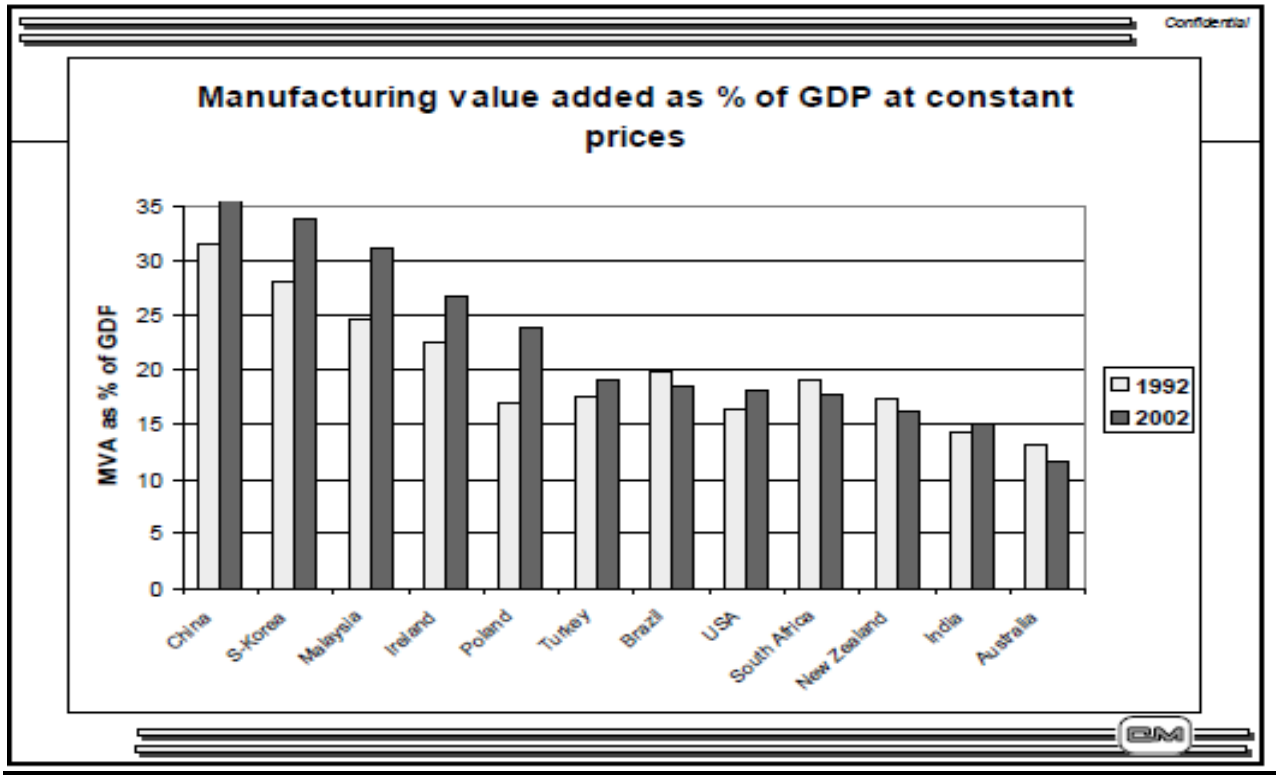
Source: Mineral Resource South Africa

Figure 6: Gold Processing per country

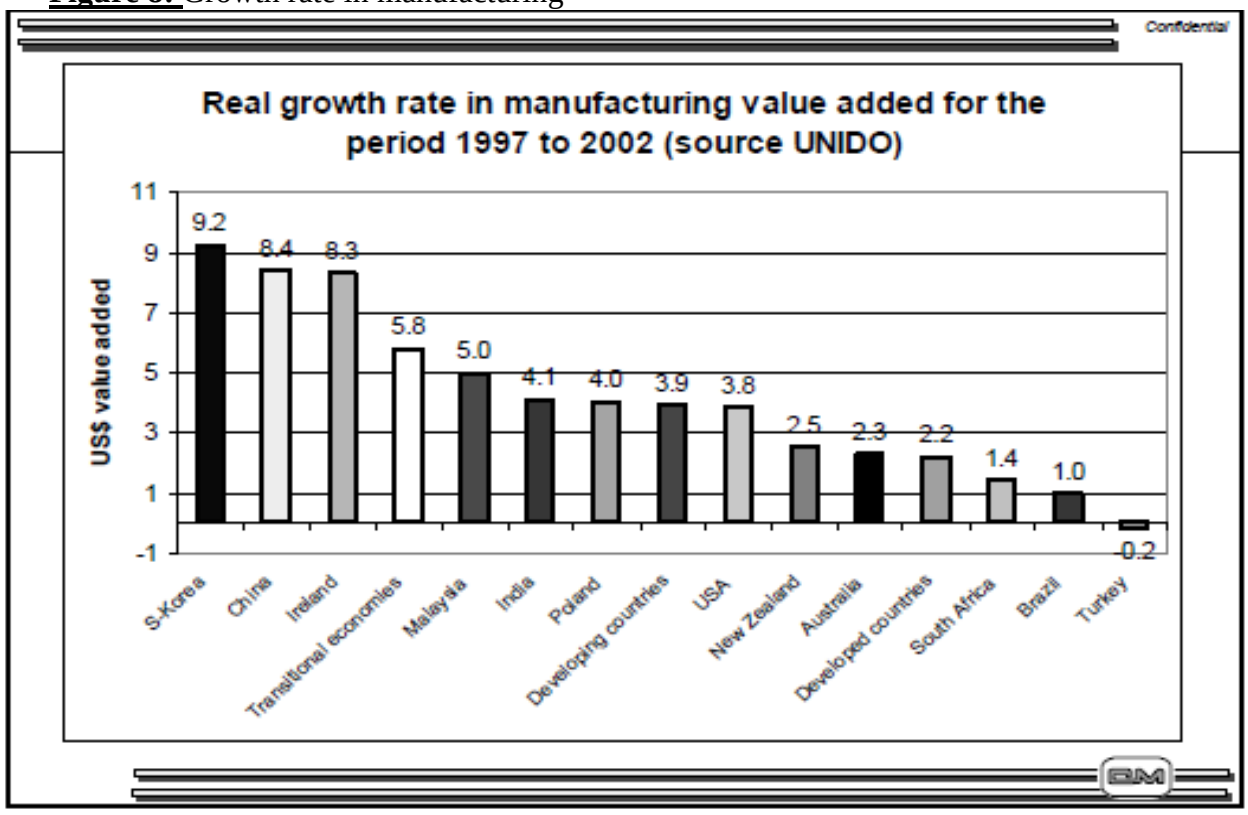


Source: Chamber of Mines South Africa

Figure 7: GDP resulting from beneficiating minerals

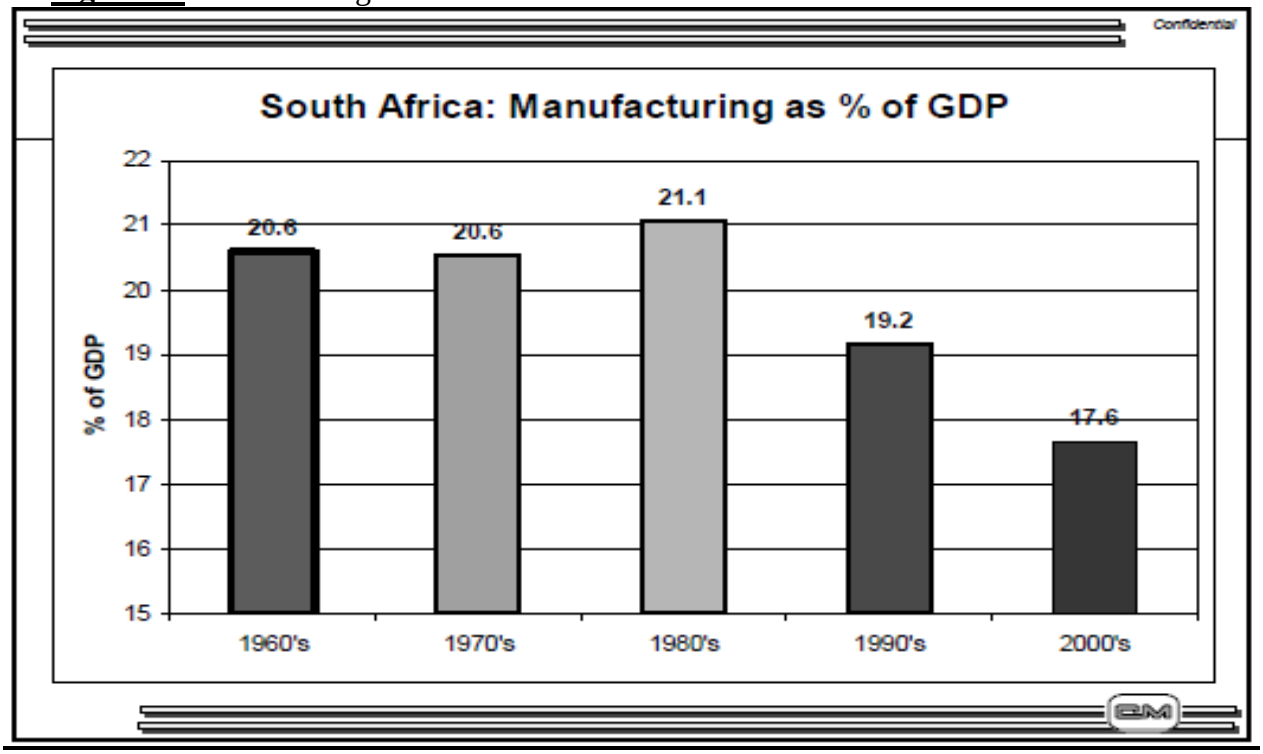


Source: Chamber of Mines South Africa
Figure 8: Growth rate in manufacturing



Source: UNIDO

Figure 9: manufacturing in South Africa



Source: Chamber of Mines South Africa

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