South African Mineral based model: A plausible option

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Abstract

South Africa is blessed with mineral endowment, producing approximately 53 different minerals from nine provinces in 2008. It is estimated that the value of South African in-situ mineral resources is worth US$2.5 trillion, making the mining industry one of the important sectors in the economy for growth going forward. In retrospect, the mining industry has been the cornerstone of the South African economy for more than 150 years because of its connectedness despite direct contribution of less than 10% to the GDP in the past five years. The connectedness of mining in the economy places it in an ideal position to contribute towards the efforts of reducing poverty, unemployment and inequality in South Africa. To achieve this ideal, the author proposes the use of Resource-based Research and Enterprise Development Model or the Linkage Model as a plausible solution. The Linkage Model is based on the economic linkage theory and it comprises of six pillars, namely government support, research funding, functional research institutions, continuous research skill supply, resource-based research output and commercialisation of research findings. The ultimate goal of the Linkage Model is to create quality employment opportunities within the mineral sector and other industries as the results of mining multipliers.

1. Introduction

South Africa is blessed with mineral endowment to the extent that in 2008 “approximately 53 different minerals were produced from 1 515 mines and quarries” (DMR, 2009a: p1). Despite this enormous economic potential, South Africa has a high unemployment rate hovering at approximately 25% compared, for example, to other BRICS countries with the unemployment rate in Russia, Brazil, China and India being at 6.6%, 6.7%, 9.6% and 10.7% respectively in 2010 (SAIRR, 2011).

In addition to the problem of the high unemployment rate, there is also a problem of dependence on social grants for those living in poverty. It was estimated that there

were 5.2 million registered South African tax payers in 2008, and 13 million social grants recipients. Out of the 13 million, 8.8 million were children (SAIRR, 2011 and Jacobs *et al*, 2010).

It can be argued that the burden of social grants on a small pool of tax payers and companies is not sustainable in the long term if deliberate actions are not taken. Assertion is made here that a viable method of bridging the inequality gap, creating employment opportunities and reducing poverty in the process has to come from a sustainable economic model that will result in economic growth and creation of entrepreneurial opportunities. A window of opportunity, as argued in this paper, is the intensification of mineral beneficiation accompanied by backward, forward and lateral economic linkages in the economy.

According to the South African government, there are four stages of mineral beneficiation, namely primary, secondary, tertiary and final stages (Table 1). The primary stage comprises of activities such as mining, recovery, reduction and smelting with the emphasis being on the conversion of raw minerals into concentrates. The secondary stage is a transition stage between the mining sector and industrial sector, and is largely concerned with the conversion of mineral concentrates into intermediate products. The tertiary stage involves refinement of intermediate products to produce high-value intermediate products. Lastly the final stage involves manufacturing of final products (MPRDA, 2002).

Table 1: The example of mineral beneficiation stages in South Africa

Stages of Beneficiation	Metals	Industrial Minerals
Primary	Saleable smelted products (copper cathode)	Processed raw material (granite blocks)
Secondary	Fabricated alloys and metals (copper tubes)	Basic final products (granite slabs)
Tertiary	Semi-manufactures articles (armatures)	Refined products (polished granite tops)
Final	Fabricated articles (electric motors)	Fabricated articles (granite workstations)

Adapted from Robinson and von Below (1990)

Notwithstanding, beneficiation (as opposed to mineral beneficiation) in this paper takes a broader view which includes manufacturing of products and capital goods and provision of services for the mineral sector as well as the establishment of enterprises and developments of new industries as the results of the demand created by the mineral sector. The historical link of mining and the rest of the economy in South Africa is a typical example of a broad definition of beneficiation in the mineral sector.

2. Historical overview of mining in South Africa

The history of mining in South Africa dates as far back as 1000 years ago when copper was mined in Phalaborwa. There is also evidence of gold mining and trading between the residents of Mapungubwe, Arabs and Oriental nations. Mining activities of the locals persisted up to the dawn of modern history of mining in South Africa, which can be said to have started in 1846 when the British took over copper mining in Namaqualand from the Dutch (Pogue, 2006).

Mining in South Africa was given impetus by the discovery of diamonds near Kimberley in 1870 and the discovery of gold in the Witwatersrand (Wits) basin. Both discoveries were so large that they attracted many international mineral sector professionals and entrepreneurs to South Africa. The arrival of professionals and entrepreneurs led to the formation of the Chambers of Mines of South Africa (CMSA)[1] in 1889, Mining Houses in the 1890s and the South African Institute of Mining and Metallurgy[2] in 1894 (Lang, 1986; Mawby, 2000; and Pogue, 2006).

From the humble beginnings in Kimberley, mining subsequently led to the formation of many towns in South Africa which include Johannesburg, Carletonville and Welkom. With more mines opening up, other economic activities followed naturally as people flocked into these towns in search of employment.

[1] Originally called the Witwatersrand Chamber of Mines
[2] Originally called the Chemical and Metallurgical Society of South Africa

This socio-economic potential of mining has always fascinated politicians. It was then not surprising that the nationalists among the Afrikaners sought to nationalise mines in the 1940s. However the idea was thwarted in favour of the establishment and strengthening of industrial parastatals such as ISCOR, SASOL, ARMSCOR and ESKOM. Through these parastatals, including those in the agriculture and transportation sectors, many employment opportunities were created for the Afrikaners. The idea of nationalisation of mines rose again in the 1990s when the African National Congress (ANC) was preparing to govern South Africa. This was again thwarted in favour of trade liberation and privatisation of parastatals after 1994. In 2010 the ANC Youth League raised the issue of nationalisation of mines again and the response was again to look for alternative solutions (Freund, 1991; Aron *et al*, 2009; and Sanlam, n.d.)

Back in the 1980s when the political tension between the Apartheid regime and black political organisations reached climax, and when it was evident that the communist-backed ANC will eventually become the government in South Africa, Mining Houses reorganised themselves for the possibility of the nationalisation of mines. For example Gencor and Anglo American Corporation (AAC)[3] bought international mining assets and separate them from the South African assets.

When the pro-capitalist ANC government allowed dual listing of big companies after 1994, companies such as Billiton[4] (a product of acquisition strategy of Gencor) and AAC took the opportunity to relocate their primary listing to foreign countries. This move resulted in South Africa not being a home to big international mining companies despite a century of mining and innovation in underground mining.

The innovation in mining was mainly driven by the Chamber of Mines of South Africa Research Organisation (COMRO), a research organisation that existed in many forms since the 1890s and formerly established in 1965. The fate of COMRO was sealed by the reorganisation of the mining industry and the establishment of SIMRAC in the early 1990s. When COMRO closed down its operations in 1993 and many scientists in its employment emigrated elsewhere, many feared that this move

[3] Now called Anglo American plc
[4] Now called BHP Billiton

will usher the death-knell to collaborative resource-based research in South Africa. Fortunately collaborative resource-based research continued beyond 1993, albeit not as strong as during the pre-1993 era. Collaborative research initiates after 1993 included DeepMine, FutureMine, CoalTech 2020 and PlatMine projects.

3. Overview of research between 1890 and 1990

The mining industry has faced many challenging problems over the years. Most importantly these problems brought about innovative solutions and in turn became significant economic activities that created employment opportunities outside the mining industry.

The nature of mineralisation in the Wits basin created the demand for explosives. To that effect, Alfred Noble, under the persuasion of Paul Kruger and the mining industry, established an explosives factory in Modderfontein in 1895. In 1903, De Beers established its own explosives factory in Somerset West. The two companies catapulted South Africa into the biggest manufacturer and consumer of explosives. In 1924 the two companies combined to form a company known today as African Explosives Limited[5]

As mining went deeper in the Wits basin, unweathered ground (virgin ground) was encountered. The nature of this unweathered ground rendered the amalgamation treatment process ineffective to the extent that it led to the closure of many mines and recession. The solution came in the form of a cyanidation process under the MacArthur-Forrest patent, which was not as effective as chlorination process, but affordable. When the patent was repealed in 1896, many mining operators jumped for the opportunity of using this cost effective ore treatment process. The CMSA was instrumental in repealing the MacArthur-Forrest patent for the benefit of mining in the Wits basin (Lang, 1986; Mawby, 2000; and Pogue, 2006).

Another issue that was of great concern in the early days of mining in the Wits basin was the treatment plant throughput rate. Due to low grades in the Wits basin, it was

[5] Source: http://www.explosives.co.za/about-ael/our-history.html

imperative to treat large quantities of ore to stay viable. To increase the milling throughput rate, metallurgists in the Wits basin collaborated to come up with the tube mill technology which replaced stamp mills that were characterised by low throughput rates. The combination of tube mills and cyanidation process increased the capacity and efficiency of the treatment plant beyond that of underground stopes (Pogue, 2006).

The response from underground was the use of portable rock-drills. Before portable rock-drills, a drilling crew consisted of 40 to 60 men with a target of a single one metre hole per day per driller and his assistant. The introduction of portable rock-drills started in 1903 and only attained full acceptance across all gold mines in the Wits basin three decades later (Pogue, 2006).

Portable rock-drills were not invented in South Africa, but they were continuously improved locally to match site conditions. By the late 1970s, hydraulic portable rock-drills were capable of producing 16.6 one metre holes per hour and pneumatic rock-drills were capable of 10.4 one metre holes per hour (CMSA, 1980).

A research by COMRO to develop rock-drills that use 100% water (and 0% oil) in the late 1970s coincided with another one that was investigating the use of chilled water delivered under pressure from surface to underground workings for cooling purposes. The combination of these two researches produced the hydropower power technology and corresponding equipment line. To that effect companies such as Hydro Power Equipment (HPE) and Joules Technology were established (Pogue, 2008).

Solutions to the mining industry problems came about due to the collaboration and strive for common objectives by various Mining Houses, glued together by the CMSA. Most significantly COMRO was instrumental in finding wide ranging solutions to problems afflicting the mining industry. COMRO was funded by mining companies (mostly gold and coal mines) but when their support waned in the early 1990s, it was absorbed by the CSIR.

The lesson learnt from COMRO is that a scientific-based initiative with adequate level of funding can be beneficial to the health of the industry. While it is unlikely that South Africa will ever see the level of collaboration between mining companies that existed prior the 1990s, the government can still create an environment where science can be used to realise more value from mining. In the absence of COMRO, Science Councils and universities can be utilised to undertake scientific research. To reach the adequate level of research output and to sustain that output, South Africa will have to improve its basic education system such that more learners can pass mathematics and physical science at matric level. Currently the basic education system in South Africa is underperforming (Rosenberg *et al*, 2009).

4. The resource-based model

The Citibank in 2010 stated that South African's known in-situ mineral resources were worth US$2.5 trillion, the largest in the world then (Creamer, 2010). Although large part of that valuation comes from the PGMs, the view taken in this paper is that mining in South Africa will continue to be an important contributor in the economy, at least in the current century. With this view in mind, South Africa will have to take full advantage of its vast mineral resources. A plausible solution could be the Resource-based Research and Enterprise Development Model or the Linkage Model in short.

4.1. The Linkage Model

The Linkage Model (Figure 1) is primarily concerned with resource-based research and enterprise development. The two combine to create a symbiotic relationship between the mining industry as the primary industry and the upstream and downstream industries. This symbiotic relationship is characterised by supply and demand which ultimately leads to the creation of first and second tier companies through the linkage effect as shown in Figure 2 (Lyndall, 2009). In the Linkage Model, the resource-based research, which largely consist of mining and mineral beneficiation research, is at the centre and knowledge creation, enterprise and product/service developments are the ultimate output products. All this, is made possible by coordinated actions of agents (from diverse backgrounds) within the Linkage Model as indicated in Figure 1.

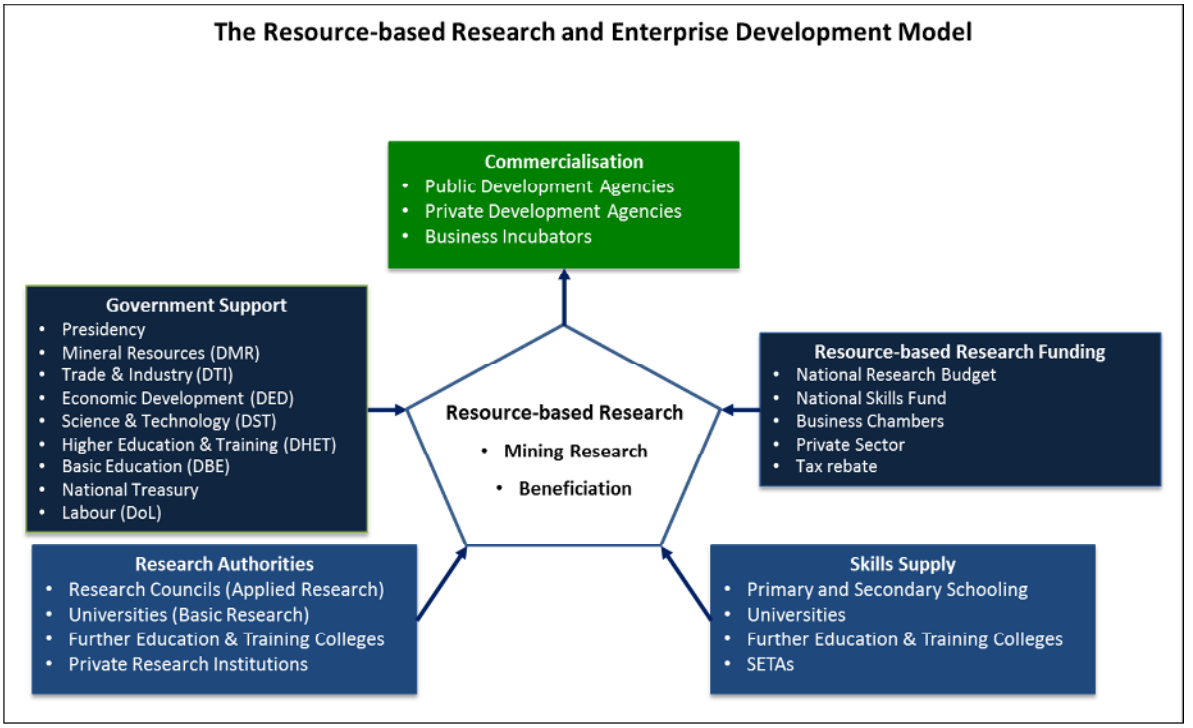

Figure 1: Agents in the Linkage Model

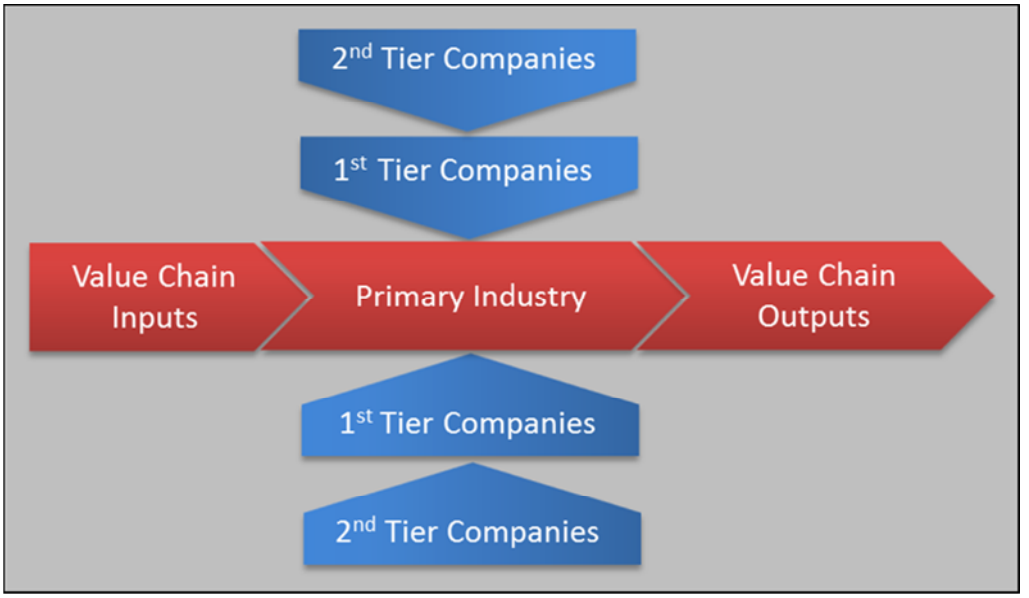

Figure 2: The economic activity due to a strong primary industry.

The six pillars or components that will ensure the success of the envisaged Linkage Model are:

- government support;

- funding scheme for mining and mineral beneficiation research;
- development of skilled personnel to generate and support new technologies;
- involvement of Science Councils and universities in resource-based research;
- mining and mineral beneficiation research output; and
- commercialisation of mining and beneficiation research findings.

By strengthening these six pillars of the Linkage Model, South Africa will create a home grown research, product/service development and enterprise development capabilities such that problems of unemployment, poverty and inequality are adequately addressed. Below is the discussion about some of the impediments, strengths and opportunities that are currently within the six pillars of the envisaged Linkage Model.

4.1.1. Government support

The strategic nature of the Linkage Model will warrant the attention and support of the government through its various departments. In particular the nine departments shown in Figure 1 will be crucial for the success of the Linkage Model. Currently the Planning Commission is looking at ways of increasing social and economic value of South African mineral resources. Form this view, it will be befitting if the Presidency, through its Planning Commission can to take the lead in the implement and execution of the Linkage Model.

The roles of the Department of Mineral Resources (DMR) and the Department of Trade and Industry (DTI) will be to create an environment where there is sufficient space in the economy from the regulation point of view to undertake mineral beneficiation. The former will have to ensure that there are sufficient quantities of mined minerals and concentrates locally to undertake mineral beneficiation. The latter will have to create a favourable regulatory and political environment for investment in the mineral beneficiation sector as well as manufacturing of equipment and components and provision of services for the mineral sector. In addition, the DMR and DTI, in conjunction with the National Treasury, will have to look at tax incentives to encourage higher level of participation in the mineral sector.

In the national interest, the DMR should allocate mineral resources with high Ricardian rents to the State owned mining company, African Exploration Mining & Finance Corporation (AEMFC), in a similar fashion as Luossavaara-Kiirunavaara Aktiebolag (LKAB) in Sweden. In return the AEMFC should open its doors for mineral-based research by Science Councils and universities. Ricardian profits could be used to subsidise resource-based research while other rents are used for organic growth.

4.1.2. Resource-based research funding

Funding in research is important. While government through the National Research Fund under the Department of Science and Technology funds research, it may be prudent to have funding mechanism specific for the mineral-based research. Apart from obvious funding from the private sector, the government could opt to use National Skills Fund (NSF) under the Department of Higher Education and Training (DHET) to fund initial activities within the Linkage Model. Between 2005 and 2010, unused funds in the NSF grew to a sizeable amount of R5 billion (Pressly, 2010).

The private sector can also partner with Science Councils and universities to undertake mineral-based research. This model is not unique though, private sector companies and Science Councils are collaborating in projects such as CoalTech 2020 and PlatMine. In fact, technology such as ConRoast furnace was produced under a similar model (Mintek, 2010). What will be different under the Linkage Model will be collaborative and coordinated research on a national scale with resources drawn from different Science Councils and universities, admittedly a feat that will require significant funding and reliable ICT infrastructure.

Business chambers can also play a role in encouraging their members to participate in the Linkage Model activities. In the past the CMSA, through COMRO, was central to the development of mining technologies such as the underground refrigeration, underground ventilation systems, portable rock-drills, and hydro-power. In the early 1990s when COMRO reduced its staff complement, some of the ex-employees started their own companies using the knowledge accumulated within COMRO over the years. To this effect, companies such as Hydro Power Equipment (hydro-power),

Joules Technology (hydro-power), Turgis (hydro-power and mining services), TLC Software (hydro-power software and instrumentation), and Bluhm Burton Engineering (cooling and ventilation) were established (Pogue, 2008). A move that is beneficial to the economy and business chambers alike.

4.1.3. Skills supply

Availability of adequate quantity and quality of skills to undertake research, product and service development, and business development (including entrepreneurship) is very important for the success of the Linkage Model. The development of the requisite skill should start from the elementary education level under the Department of Basic Education (DBE) and continues all the way to the tertiary education level under the DHET.

Unfortunately South Africa is not doing well in developing requisite skills for the mineral-based research. In 2007 South Africa produced 26 doctorates per million citizens (or 1 274 doctorates), compared to 427 (3 886) in Sweden, 375 (1 988) in Finland, 264 (5 544) in Australia and 201 (60 742) in USA. The aforementioned countries are among the competitors of South Africa in mining, mineral beneficiation, product/service development and manufacturing of equipment for the mineral sector (ASSAf, 2010).

The South African situation is dire when considering that only 92 of 1274 doctorates in 2007 graduated in the category of engineering sciences, materials and technologies. Out of the 92 graduates, 28 and 17 were from the field of electrical and electronic engineering, and mechanical engineering respectively. These two fields of study consistently produce a relatively large number of doctoral graduates (ASSAf, 2010). In the corresponding period, the University of the Witwatersrand (the South African biggest university in mining) produced only 1 doctoral graduate in mining engineering, pointing to a possible capacity problem with respect to the local resource-based research (Wits University School of Mining Engineering, 2011).

Lombard and Stadler (1980), Tregenna (2007), and Lyndall (2009) have painted a picture of the South African mining industry that exports high ratio of its minerals by

value and imports high ratio of capital goods by value. This situation that can be linked to the enclaved nature of the mining industry where local economic activities are by passed in favour of those of more advanced countries. Fortunately this situation can be reversed if home grown capabilities are created. Unfortunately for South Africa, few doctorates in the disciplines central to the mineral sector will do very little to change the reliance of the local mining industry on foreign markets, an act that undermines the local manufacturing sector and economic growth according to ASSAf (2010).

4.1.4. Research authorities

The Science Councils, universities and private research institutions have a crucial role to play in the Linkage Model. South Africa has some of the best universities in Africa and Science Councils capable of undertaking resource-based research on a large scale. However funding model for the Science Councils at this stage does not support fundamental research, something that is required if more capital goods for the mineral sector are to be developed and manufactured locally. At this stage the Science Councils in the mineral sector get 60% to 70% of their income from commercial projects.

With regard to private research institutions, their participation in the resource-based research is notable. COMRO was actively engaged in various research projects between 1965 and 1992 in all areas that impacted on gold and coal mining. While it is acknowledged that knowledge created in the private sector is private, some form of knowledge exchange between public and private research organisations should be encouraged. This is crucial when it is considered that the private sector is more likely to commercialise research outputs than public institutions.

4.1.5. Mining and mineral beneficiation research

While South Africa is not the leading producer of gold anymore, it is estimated that the country still have one of the largest known gold resource in the world, locked in the Wits basin. The gold in the Wits basin is locked in underground pillars; unmined marginal ground that fell below the cut-off grade at some stage in the past; and deep

deposits (beyond 3km deep) in the Wits basin. There is also gold in unprocessed slimes dams and in the deposits of the Bushveld Complex.

New mining methods and technologies are needed to mine the currently locked gold. Similarly new beneficiation techniques are required to beneficiate titanium ore extracted from the Bushveld Complex and manufacture resultant products locally. To this effect, the Council for Scientific and Industrial Research (CSIR) has established a Titanium Centre of Competence with the target of producing 20 000tpa of titanium powder by 2020. The titanium resource in the Bushveld Complex is estimated to be the second largest resource after the Australian deposits (CSIR, 2010).

It is safe to say that mineral-based research has always been the hallmark of South Africa, although on a small scale and isolated basis. For example Mintek has been collaborating with Anglogold Ashanti (and Harmony in the past) in the AuTek project to find new industrial applications of gold in areas of catalysis, nanotechnology and biomedical science (Mintek, 2010). Recently Anglogold Ashanti has embarked on a five year project to develop an automated continuous mining process aimed at unlocking gold resources as deep as 5km below surface. To achieve the terms of the project, Anglogold Ashanti has assembled a group of innovators, researchers and academics around the world. It is envisaged that this project will replace the cyclic operation of underground gold mining and the need for people to work in dangerous stopes, with a continuous automated mining technology (Creamer, 2011).

Assertion is made here that isolated pockets of research excellence in the mineral sector could gain more leverage if they are brought under the coordination and the control of the Linkage Model.

4.1.6. Commercialisation of research findings

The level of research in the mineral sector is not consummated by product development and commercialisation. Failure to commercialise research findings could result in a loss of opportunities. For example, many of the novel mechanisation technologies used in coal mines today originated in the commandist countries (mainly USSR). However, lack of commercialisation capacity in the commandist

countries led to Western companies seizing the opportunity to commercialise their mechanisation research findings. The consequences of this action were that Western economies benefited substantially more than commandist economies despite the latter being responsible for the ideas in the first place (Wagner and Fettweis, 2001).

To avoid repeating mistakes of the commandist countries, it is important to establish bridges between research, development and commerce through enterprise linkage such that viable economic clusters around the mineral sector are created. In a free market world, meaningful job opportunities will arise if research findings are commercialised cost effectively.

A suitable model for start-up enterprises wishing to develop new technologies or improve existing technologies could be business incubation. The business incubation model, particularly the one that focuses on technology, started in the late 1950s at the Massachusetts Institute of Technology (MIT) in USA. In South Africa, although not used extensively, business incubators have achieved a 78% survival rate in start-up businesses after three years of operation (Leeuw, 2005).

The focus though should be on technology intensive start-ups that would support modern hi-tech mines. The hi-tech mines have capability of inducing job opportunities in related and supporting industries through the linkage effect. For example, Lindall (2009) estimated that a single PGM mine with a capacity of 200 000 tons per month can consume up to 100 000 assemblies from 2 000 to 5 000 firms.

Given that there are at least 45 operating platinum mines is South Africa (DMR, 2011), the prospect of creating jobs in supporting industries is huge provided that the required equipment, components, assemblies and services are home grown.

5. The implementation of the Linkage Model

A plausible name for the institutionalised Linkage Model is the Resource-based Research and Enterprise Development Initiative or simply the Linkage Initiative. The

successful implementation of the Linkage Initiative will rest on the effectiveness of its envisaged steering committee outlined in Figure 3. Due to the contemplated strategic and multi-disciplinary nature of the Linkage Initiative, stemming from the Linkage Model, it will be ideal if its operations could be coordinated by the Planning Commission. Ideally the chairperson of the steering committee should be a senior official at the Director General level in the office of the Planning Commission. This is appropriate because one of the issues that the Planning Commission is looking at is to increase the social and economic value of the South African mineral endowment.

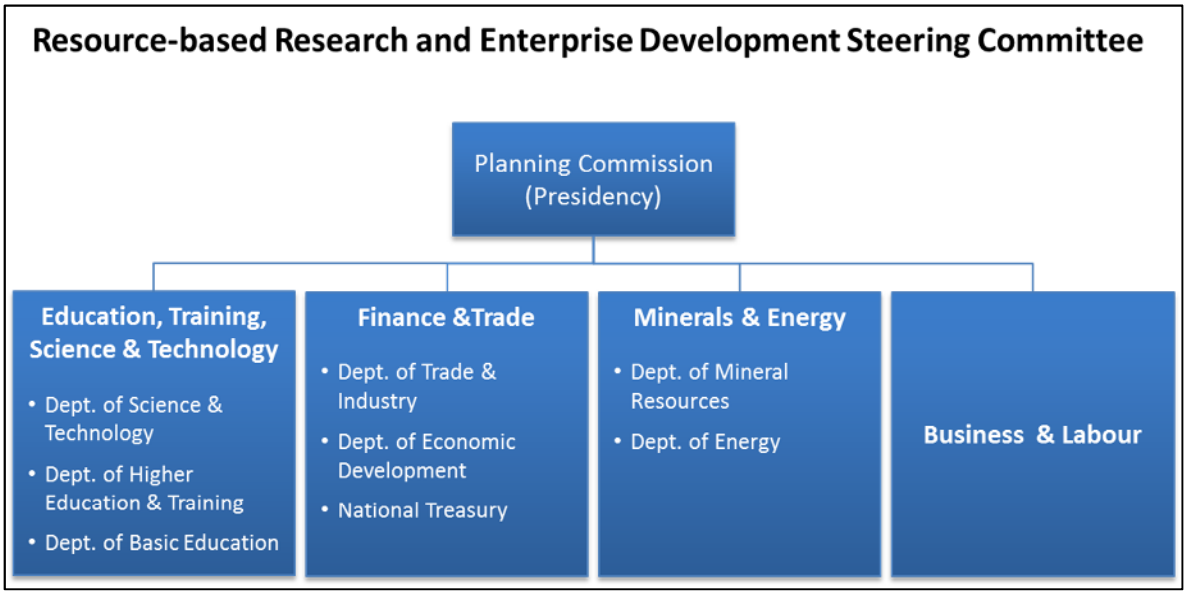

Figure 3: Proposed composition of the steering committee responsible for the Linkage Initiative

The steering committee should be made up of senior officials from the government, business and labour sectors grouped into the following clusters:

- Education, Training, Science and Technology;
- Finance and Trade;
- Minerals and Energy; and
- Business and Labour

All government departments identified under different clusters will not necessarily be required right from the inception of the steering committee. For example, the

Department of Energy may not participate at the beginning but as the coverage of the Linkage Initiative expands to include research and beneficiation of oil and gas, it may be prudent for it to become a member of the steering committee. Similarly other departments may be included or excluded when the need arises.

All appointed public servants under different clusters serving in the steering committee should be senior officials at the Director General level. Similarly business and labour representatives should be on a level where they are able to take decisions on behalf of their constituents. Most importantly business representatives should be biased towards entrepreneurship. This is to ensure that the focus is turned towards enterprise development, which is required for the commercialisation of research findings. Care should be taken to separate distinct business of the steering committee from the agenda of NEDLAC.

While the steering committee will be providing direction in so far as the resource-based research and development is concerned, the real activities of the Linkage Initiative should be executed by representatives of agents identified in Figure 1.

6. Conclusion

Given that mines are capital intensive, the idea that South African mines will create more jobs than the current level going forward is misplaced. A plausible solution is to focus on creating job opportunities in the labour absorptive industrial and services sectors. This can be achieved by implementing the Linkage Model in totality. The government through its various departments must be fully committed to the success of the Linkage Model. There has to be enough funding from the government and private sector to make the model work. In addition, there has to be enough researchers and research facilities that can be used for mining and mineral beneficiation research. This can be achieved through the cooperation of Science Councils, universities and private sector.

Ultimately, the Linkage Model must lead to knowledge creation and commercialisation of research findings through product/service development and enterprise development. The latter can be achieved by using business development agencies in conjunction with other models such as business incubation. The

advantage of business incubation is that it gives a researcher/entrepreneur time to perfect his/her invention and business model while it provides the necessary support during the early days of a business.

The relevance of the Linkage Model does not only lie in its resonance with the National Development Plan of 2011 produced by the Planning Commission, it also provides a plausible alternative solution to the call for the nationalisation of mines. The solution entails remedying structural problems in the South African economy such as the poor administration of the basic and post matric education; low number of doctorates per capita in South Africa compared to its international competitors; low research output in mining; low capacity to develop and manufacture products based on research findings; and low entrepreneurial activity. The endemic nature of these structural problems requires long term political and corporate commitment.

The Linkage Model is not unique though. There are other mineral sector based initiatives that seek to address issues of poverty, unemployment and inequality in South Africa and the Linkage Model should be regarded as part of these initiatives.

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