Original Research Article

The Development Minerals Value Chain Policy Model: *The Case of Rwanda in the East African Region*

Abstract

The objective of this policy paper is to examine, assess and propose a solid theoretical model that will assist in [1] assessing the current status of development mineral value chains; [2] identifying social economic activities for mining systems, and [3] proposing consistent recommendations on policy options and other incentives necessary to enhance the contribution of the mining sector and their value chains to sustainable social economic development in Rwanda.

This is a theoretical paper based on literature reviews on policy models using classical Michael Porter's (1979) Value Chain Model, (VCM) articulating full range of social economic activities – including design, input sources, production, marketing and distribution – businesses conduct to bring a product or service from conception to delivery. Value chain analysis has been a strategic policy tool used to analyze internal firms, sectorial and national operational objectives and strategies given external environments.

The policy findings and solution emphasizes the importance of strengthening all optimal mineral-based linkages while resources are extant so as to maximize the developmental and inter-generational impact of those resources. The nation's mining policy objective is to ensure efficient and effective utilization of mineral deposits, explorations, extractions, processing, beneficiations, trades and marketing, and final consumptions systems by national social economic entities such as households, firms and communities.

The paper recommends that Rwanda government to develop and achieve the "transparent, equitable and optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development. The Rwandese must ensure that all social economic entities have to share a common goal of achieving profitability, productivity and optimal cash flow for the entire development mineral value chain. It follows that national development mineral operations management, implemented through value chain management, requires a new, operational and different perspective of relationship management.

Key Words: Development Minerals Value Additions Rwanda

1. Introduction

1.1.Background

1.1.1. Basic Data and Information

Small and landlocked, Rwanda is a small, hilly, fertile and beautiful country with a population of about 12.5 million people (2018). Table 1 summarizes basic data and information for Rwanda. It borders the far larger and richer Democratic Republic of Congo, and East African neighbours, Tanzania, Uganda, and Burundi. Rwanda aspires to achieve the social economic living standards of upper middle- and high-income countries by 2035 and 2050 respectively. This will be achieved through a series of seven-year National Strategies for Transformation (NST1), underpinned by sectoral strategies focused on achieving the Sustainable Development Goals (SGD-2030). The Rwanda Vision 2050 recognizes the role played by non-metallic mineral products, among other stand-out performers, in ensuring the country achieved an average about 10 % growth per annum for sustainable development.

Rwanda is one of the world's producers of tin, tantalum, and tungsten (3Ts) and also currently exports gold and gemstones. Rwanda 3Ts Minerals Production was reported at 4,337.000 Metric Ton in Dec 2019. This records a decrease from the previous number of 5,237.000 Metric Ton for Dec 2018. Rwanda also possesses a variety of minerals such as silica sands, kaolin, vermiculite, diatomite, clays, limestone, talcum, gypsum, and Pozzolana. Small-scale mining accounts for around 80 percent of the country's mineral output.

The current mining opportunities include expansion and development of mineral exploration (Tin, Tungsten, Coltan, and gemstones), acquisition and development of industrial mining capital equipment, machineries and technologies, targeting value-addition, enhancing partnerships with local mining companies, promoting and supporting trade in minerals and intensifying smelting in Rwanda. Also, the government is eager to formalize the sector, attract international mining investors, and increase processing of minerals in the country.

Based on the existing mineral resources, systems and the envisaged potential role in the domestic and regional economies, Rwanda's current 30-year Vision (Vision 2050) has identified development of mineral resources as one of the strategic pathways of social economic transformation. Also, the Government of Rwanda (GoR) intends to diversify mineral production from the dominant 3Ts to develop minerals which have critical roles in infrastructure development as well as spawning other industries in the domestic economy.

Although there are several national economic policies and strategies for promoting value addition, there is a lack of a sector specific policy and strategies for promoting value addition for the development of minerals. The current Made in Rwanda Policy strategies are too generic and not specific for development of the mining sector. Like other African countries, Rwanda has to improve the current policy, legal, regulatory and institutional frameworks of the mining sector in order to increase efficiency and effectiveness for transformation of the sector to internationally acceptable levels.

Table 1: Rwanda Basic Data and Information

Location
Central Africa, east of the Democratic Republic of the Congo, north of Burundi
Geographic Coordinates
2 00 S, 30 00 E
Total Area
About: 26,338 sq km
Land Boundaries
Border countries (4): Burundi 315 km, Democratic Republic of the Congo 221 km, Tanzania 222 km, Uganda 172 km
Natural Resources
Gold, cassiterite (tin ore), wolframite (tungsten ore), methane, hydropower, arable land
Land Use
Agricultural land: 74.5%
Arable land: 47%
Other: 7.5%
Environment Issues
Deforestation results from uncontrolled cutting of trees for fuel; overgrazing; land degradation; soil erosion; a decline in soil fertility (soil exhaustion); wetland degradation and loss of biodiversity; widespread poaching
GDP real Growth Rate
2.0% (2020 est.)
9.4%. (2019 est.)
8.3% (2017 est.)
GDP per capita
$2,225 (2020 est.)
$2,100 (2019 est.)
$1,975 (2018 est.)
GDP Composition by Sector of Origin
Agriculture: 30.0% (2020 est.)
Industry: 17.6% (2020 est.)
Services: 52.4% (2020 est.)
Labour Force
6.325 million (2020 est.)

Date Sources: CIA 2021, Rwanda Development Board, 2021 and AfDB, 2021

1.1.2. Review of Rwanda Development Mineral Policy Issues

Development minerals are natural resource minerals that are mined, processed, manufactured, used and domestically playing an oversized role in social economic development, especially in the areas of infrastructure, housing building, road constructions, agriculture and infrastructure reconstruction, as well as supporting a large number of formal and informal micro, small and medium-sized domestic enterprises, (UNDP, 2018a and 2018b). There are three current, interesting and linked policy issues on the role and importance of the mining sector in Africa.

The first mining policy issue is that many African countries are argued to be richly endowed with varieties of mineral resources, although their viable potentials are yet to be fully explored and established, (Uongozi Institute, 2017). Formal mineral industries in many African countries are fairly infant, accounting for a negligible share of GDP. In most cases mineral commodities are exploited and exported in raw forms; limited or low levels of production technologies and the workforce is dominated by informal and semi-skilled artisan labour, (Biryabarema, 2019).

The second mining policy issue is a fact that many African countries boast diversities and potentialities of these development minerals, (Uongozi Institute, 2017). Mining and quarrying sectors have got potential to become one of the key drivers of social economic transformation because of its high probabilities for increased value additions, growth contributions and employment and forward linkages that will overall generate substantial social and economic benefits to the Rwandan society, (Rupert and Mitchell, 2014 and Republic of Rwanda, 2017a).

The third mining policy issue is about increasing competitiveness in global mineral market places. The establishment of new trade agreements between countries, firms, and improvements in financial resource, technologies, communication, transport and other resource systems are just a few of the factors that have enabled nationals and firms to develop optimal global value chains. The openings of the global marketplaces have served to introduce more competitors and make competition intense, thus making strategic value chain design even more important for achieving success.

Like other African countries, Rwanda is confronted with these issues and operates in the first mining stage where the least value is added and even then not comprehensively and the major proportion of the overall added value is done abroad. Key constraints in the Rwanda mining sector include low level of technology used in the explorations and extractive processes, resulting in limited discoveries and recoveries of ores; insufficient power supplies and frequent outages; continued export of minerals without value additions; limited linkages to the rest of the economy, high cost of beneficiation especially for the tantalite, tin and tungsten products; shortage of professional skills in all the stages of the minerals value chain; decades-long focus on exploitation of tantalite, tin and tungsten products, (Republic of Rwanda, 2017a)

Currently, many African countries are conducting assessment studies on the transformation and management of development minerals. The objectives of these studies are to improve the policy, regulatory and institutions systems harnessing natural resources for accelerated sustainable social economic development in Africa, (UNDP 2018a).

The objectives of these policy oriented studies are accomplished through consultation with key development minerals including from mines to final markets. Both primary and secondary data and information are collected, managed and analyzed. Existing secondary data and information are used to complement the basic primary data collected during the field research surveys. Primary data and information collection consist of site assessments, telephone consultations, focus group discussions and indirect interviews at mining and quarry sites, markets, and consumers of development minerals. Consultative meetings with local and central stakeholders are conducted, (UNDP, 2018a).

However, these development mining studies used variation value chain and ad hoc policy analysis models, (UNDP, 2018a and 2018b). The government of Rwanda adopts moderate policy framework whereby the mineral value chains include: (i) extraction and its related processes such as exploration, construction, mining, (ii) transformation with mineral processing, smelting and refining, semi-fabrication, and final product manufacture, and (iii) consumption which include marketing, and sale of goods to consumers in their final form, (Republic of Rwanda, 2017a).

It is unfortunate to note that many of these African mining policy studies either are [1] not founded on solid Value Chain Models or and [2] not conversant on the sequencing and interdependent steps, chains of core mining systems operations, (UNDP 2018a and 2018b). Concepts of Values, Value Chain, Supply Chains and Global Value Chains were mentioned or used to different meanings and often misused. *Many of final mining policy findings are too general, complex; covering and mixing almost all standard policy mining issues and have no strategic and purposively African policy implications, directions and recommendations*, (Uongozi Institute, 2017).

1.2.Objective of the Paper

The objective of this policy paper to examine, assess and propose a solid theoretical model that will assist in [1] assessing the current status of development mineral value chains; [2] identifying social economic activities, strengths, weaknesses, opportunities and challenges for mining systems, and [3] proposing consistent recommendations on policy options and other incentives necessary to enhance the contribution of the mining sector and their value chains to sustainable social economic development in Rwanda.

1.3.Outline of the Paper

The paper has six main sections. Section 1 was the introduction consisting of the background and objectives of the paper. Section 2 summarizes the basic value chain model- Michael Porter's, (1979). Section 3 defines basic mining concepts: elements, chains and interdependencies. Section 4 presents the main mining sector value chain model consisting of mining system operations, none-core mining systems and operations, core mining operational stages, phases and activities. Section 5 presents main paper findings namely; policy model solutions, options and targets. The last section 6 is a conclusion consisting of policy model solutions, options and targets and proposed Rwanda national mining policy perceptive.

2. Basic Value Chain Model: Michael Porter's (1979)

This paper is founded on a classical Michael Porter's (1979) value chain model which articulates a full range of social economic activities – including design, production, marketing and distribution – businesses conduct to bring a product or service from conception to delivery, (Alain Martel and Walid Klibi, 2016). The value of any product or service is the result of its ability to meet a customer's priorities. Customer priorities are simply the things that are so important to customers that they will pay a premium for them or, when they can't get them, they will switch suppliers. Value chain analysis describes the full range of activities needed to create a product or service that allows businesses to examine their activities and find competitive opportunities. The purpose of a value-chain analysis is to increase production efficiency so that a corporate firm can deliver maximum value for the least minimum cost.

Value chain analysis has been a strategic policy tool used to analyze internal firms, sectorial and national operational objectives and strategies given external environments, (David Walters, 2002). Its policy goal is to recognize which activities are the most valuable (i.e. are the source of cost or differentiation advantage) to the firm and which ones could be improved to provide competitive advantage, (Julia Connell, *et al*, 2018). With value chain analysis, we can easily identify those interdependent activities where we can quickly reduce cost, optimize effort, eliminate waste, and increase profitability. Analyzing these activities also gives insights into strategies that bring greater value to the end user, (Alain Martel and Walid Klibi, 2016).

Any product or service is really the result of a complex set of interdependent activities: myriad economic transactions and institutional arrangements among suppliers and customers, employees and managers, teams of technical and organisational specialists; what we usually think of as prospects or services are really frozen activities, concrete manifestations of the relationships among actors in a value creating system. The idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing (or service) organization as a system, made up of subsystems each with inputs, transformation processes and outputs, (David Walters, 2002).

The classical concept of value chain as decision support tools was added onto the competitive market strategies paradigm developed by Porter (1979). In Porter's value chains, inbound logistics, operations, outbound logistics, marketing and sales, and service are categorized as primary activities, (Julia Connell, *et al*, 2018). Secondary activities include procurement, human resource management, technological development and infrastructure (Porter 1985, pp. 11–15). The emergence of global value chains (GVCs) in the late 1990s provided a catalyst for accelerated change in the landscape of international investment and trade, with major, far-reaching consequences on governments as well as private sector enterprises The value chain that results meet expectations of all stakeholders, (Sören Scholvin, *et al*, 2019): End-user customers 'buy' the value offered (through the value proposition), while reseller and manufacturing and logistics stakeholders' objectives are met in terms of their own profitability, productivity and cash flow objectives. The principle of value chain strategy, structure and operations is that all stakeholders benefit from involvement: either they cannot compete as independent units, because they do not command the competencies (or resources), or membership changes the 'shape and size' of the offer such that their individual gains are increased from cooperating within the value chain structure.

3. Definitions of Basic Mining Concepts: Elements, Chains and Interdependencies

Section 3 reviews basic value adding mining concepts and systems to include [1] development mineral deposits; [2] development mineral exploration, [3] mining extraction operations and activities, [4] mineral processing, [5] mineral beneficiation and manufacturing processes, and [6] mineral trade, uses, consumption and markets.

3.1.Development Mineral Deposits

The review of development mineral value chains starts with assessment of initial (*element or base)* available types, quantities and qualities of mineral deposits, (M_0) in Rwanda. The development mineral deposits are naturally occurring accumulations or concentrations of metals or minerals of sufficient size and concentration that might, under favourable circumstances, have economic value, (Rwanda Bureau of Standards, 2011). From a geological point of view, a simple genetic classification of mineral deposits encompasses four main groups: magmatic, hydrothermal, sedimentary, and metamorphic/metamorphosed, each of them with several types and subtypes. A field is a mineral deposit containing metal or other valuable resources in a cost-competitive concentration. It is usually used in the context of a mineral deposit from which it is convenient to extract its metallic component. The ore deposits are exploited by mining in the case of solid mineral deposits (such as iron or coal) and extraction wells in case of fluids (such as oil, gas, or brines)

3.2.Development Mineral Exploration in Rwanda

Operationally, mineral exploration, (*ME*) is a complete sequence of scientific and technical activities, (Rwanda Bureau of Standards, 2011). It ranges between searching for a new mineral prospect (reconnaissance) and evaluation of the property for economic mining (feasibility study). It also includes augmentation of additional ore reserves and resources in the mine and total mining area.

Various techniques are used in the initial data and information searches in order *to add values for mineral deposits*, an activity called *prospecting.* Once a discovery has been made, the property containing a deposit, called the *prospect*, is explored to determine some of the more important characteristics of the deposit. Among these are its *known* size, shape, orientation in space, and location with respect to the surface, as well as the mineral quality and quality distribution and the quantities of these different qualities.

In searching for valuable minerals in many developing economies, the "*traditional prospector*" or and artisanal miners relied primarily on the direct observations of mineralization in outcrops, sediments, and soil. Although direct observations are still widely practiced, modern prospecting is necessary and sufficient conditions for accessing financial resources and mobilizations. The basic prospecting employs a combination of geological surveys, geophysical, and geochemical tools to provide indirect indications for reducing the search radius. On the basis of such preliminary exploration studies, a number of prospects and or concessions are identified. The most promising of these *value addition services* become the focus of a field RMB exploration programs and activities. The Rwandese geological survey activities have included identifications

areas with mineral potential and promote them for investment, produce basic geo-data for use in mineral exploration and find new resources for sustainability of the mineral sector, emphasis on the responsible environmental practices and to include environmental reporting based on sustainable development as part of the exploration, survey and evaluation process and RMB has actively provided information for the general public and decision makers on the importance of mineral resources and their sustainable use.

3.3.Mining Extraction Operations and Activities in Rwanda

Mining is the extraction of valuable minerals or other geological materials from the Earth, usually from an ore body, lode, vein, seam, and reef or placer deposit. These mineral deposits form a mineralized package that is of economic interest to the miner, (Barry and Finch, 2015a). Mineral extraction is the procedure of excavation and recuperation of mineralization and associated waste rock from the crust of the Earth to derive values, incomes and profits. In this process, mineralization is obtained from the ground using surface and/or underground mining methods. Extractive industries represent a large growing social economic activity in many rural areas but the wealth generated does not always lead to rural sustainable development and inclusive growth. Many developing countries use two types of mineral ore extraction

Open cast mining is the preferred method for the extraction of ore from deposits that are close to the surface, since the cost of ore mined is lower than that for underground mining, (Rwanda Bureau of Standards, 2011). Other factors that may influence the decision about whether mining in open cast or using underground methods includes the ore grade, the geometry of the deposit and other physical characteristics such as topography.

In underground mines, the ore is extracted through a series of vertical shafts and ramps and horizontal drifts and adits. Extraction is more selective than in open pit mining, and the ratio of waste rock to ore generated is much lower. Waste rock should be used as mine backfill to provide roof and wall support underground. Waste rock, that is, not used for construction or as backfill may be disposed of on the surface.

The current methods used depend on the type of mineral resource that is mined, its location at or beneath the surface, and whether the resource is worth enough money to justify extracting it. Each mining method also has varying degrees of impact on the surrounding landscape and environment. The location and shape of the deposit, strength of the rock, ore grade, mining costs, and current market price of the commodity are some of the determining factors for selecting which mining method to use.

3.4.Mineral Processing

“As-mined” or “run-of-mine” or “crude ore” consists of valuable minerals and gangue. Primary mineral processing, also known as *ore dressing, ore beneficiation, mineral dressing, or milling*, is an act of treating crude ores and mineral products in order to separate the valuable minerals from the waste rock, or gangue, (Balsubramanian, 2015). It is the first process that most ores undergo after extraction in order to provide a more concentrated material for the procedures of extractive metallurgy. Ore is an aggregate of economically important minerals from which a

valuable metallic constituent can be profitably mined and extracted. Most of the rock deposits contain metals or minerals, (Balsubramanian, 2015).

When the concentration of valuable minerals or metals is too low to justify mining, it is considered to be a waste or gangue material. Within an ore body, the valuable minerals are surrounded by gangue minerals. It is due to this primary reason we need to transform mineral processing systems and technologies. It is necessary to liberate and concentrate those valuable minerals from the bulk mass through a suitable mechanical treatment, (Balsubramanian, 2015 and Barry and Finch, 2015).

3.5.Mineral Beneficiation and Manufacturing Processes

Beneficiation is the transformation of a mineral, or a combination of minerals, into a higher-value product, which can either be consumed locally or exported, (Biryabarema, 2019). Beneficiation is the process where ore is reduced in size and ganger separated from the ore. Since all iron ore deposits have unique mineralogy, the beneficiation process is specific to each deposit. Beneficiation entails the transformation of a mineral (or a combination of minerals) to a higher value product, which can either be consumed locally or exported. The term is used interchangeably with "value-addition. Beneficiation of local mineral resources is a major policy objective for Rwanda as it pursues higher income status. A local mineral processing industry would raise the value of exports, generating higher employment levels and incomes for the industry and also raise mining contribution to GDP, (Biryabarema, 2019). However, a semi-skilled workforce, limited access to infrastructure, and insufficient capital investment continues to impede modernization of mining operations and limit mineral value additions

3.6.Mineral Trade and Markets

Mineral trade involves the transfer of goods and services connected with raw minerals, semi-processed, processed and final mineral products from one person, country or entity to another, often in exchange for money. Economists refer to a system or network that allows trade as a market, (Jessica Elzea Kogel, *et al*, 2009). And the "market" is a physical, ideal or and hypothetical places where buyers and sellers of a given commodity meet to determine prices, quantities and exchange modalities. Mineral markets are material goods markets, and many are regarded as world markets because of the easy negotiability of the traded commodities. Strictly speaking, markets for any particular mineral may exist at several stages of exploration, extraction, production, process and for several levels of qualities, (Gocht, *et al* 1988).

In practice, however, the market usually referred to is that of the standard trade quality for the mineral commodities most important in world trade: today, for industrial, constriction, dimension and semi-gemstone development minerals. These are homogeneous, fungible commodities negotiable on exchanges at an approximately uniform national, regional and world market price.

The total mineral trade in Rwanda consists of both domestic and foreign trade, (Republic of Rwanda, 2017a). The domestic development mineral trade consists of final consumptions, retail and wholesale trade. The retail trade consists of the sale of mineral goods or mechanized from a very fixed location (such as a mining and quarries), transport, shipments and online or by mail,

in small or individual lots for direct consumption or use by the purchasers. Wholesale trade is defined as traffic in relative bulky or large quantities of development minerals that are sold as merchandise to retailers, or to industrial, commercial, institutional, or other professional business users, or to other wholesalers and related subordinated services.

3.6.1. Development Mineral Market levels

The literature reviews suggest existence of three levels of the Rwanda development minerals markets, namely the mining and quarry area, the primary market in nearby villages and towns, the secondary or and export markets in Kigali, (Republic of Rwanda, 2017a). Each of these has its own features. Modern financing and information communications technologies are telescoping the local and international developing minerals market chains, eliminating many bureaucratic levels.

First Development Mineral Market Level: The mining and quarry areas

The first sale of raw development minerals often takes place immediately at the mining and quarry sites. At this first level market stage, artisanal miners and small scale mine workers and owners are the main market suppliers and participants. The organization of artisanal mining and small scale quarries favors this arrangement. Rwanda artisanal miners and workers refuse to work on salaries, preferring the prevailing system of immediate and direct production sharing between workers and the mine and quarry licence holder and/or pit owners. Mine workers could market their "shares" openly in nearby mining villages and small towns. These many social economic participants, prices and quantities are market determined.

Second Development Mineral Market Level: The Primary Market

In mining and quarry villages a short distance from the mines and quarries one *finds second and primary markets where production enters quasi legal channels*. Most buyers and sellers have mining and or mineral trade licences. The degree of market activities in development mining and quarry villages depends mainly on the quantity and quality of the recovered minerals. The main participants in this market level are legal social economic entities owning and managing mineral and or quarry licences. They later frequently shuttle between the mining and quarry sites, the primary markets and processing plants. For the case of amethysts, local market days mine workers are also active, selling small parcels of good semi-gem quality stones. Mining licence holders are from major towns and even outside the country frequently visit mining villages. The market size varies considerably depending on the type of mineral production and the level of domestic and international demands. When amethyst production is of good quality, color, high and mining licence holders have received international orders, market volume wells quickly.

Third Development Mineral Market Level: Kigali City Market and Exports

The third development mineral markets are in Kigali where most mineral and trade licence holders have established permanent offices. The main markets for all development minerals are in Kigali, but few newly established towns are trying to compete and these also have their roles. In such markets, the existing infrastructure and facilities allow for easy export and access to

foreign buyers. These newly established market towns need to have good road access, market promotions, ICT and financing systems, which are essential for dealers to communicate with their potential buyers and consumers. The major participants in these markets are mining and trade licence holders, financial markets, consumers and general trades. There is an increasing specialization in the semi-gem markets, particular traders who buy mainly one type of dimension stones. Most development mineral mining licence holders for dimension stone, however, put out buy orders whenever they have an international buyer for a particular type of stone.

The export market is part of the third market levels and normally it depends on the location of transactions as well as the destinations of the purchased minerals. The export market can appear in several forms. The market can appear when a foreign buyer is purchasing from mining and trade licence holders at their offices or during mineral trade shows. Some illegal foreign buyers also like to travel to mining areas to buy directly from miners, although this is prohibited in Rwanda.

For some development minerals trade from artisanal production, Rwanda is part of a regional network that covers all three Great Lakes countries (Uganda, Rwanda and Burundi), Eastern Democratic Republic of Congo. Development mineral trades from Rwanda to other countries have been relatively limited to date, with relationships focused on broad EAC regional cooperation and development mechanisms of internal development, as opposed to establishing specific import and export to these mineral resources. Although the Rwanda does not yet represent a vital trade partner to the EAC region measured by volume, the criticality of some of the commodities produced increases the importance of the region significantly. It is further notable that certain of the mineral commodities that have been deemed 'critical minerals' to the EAC are also globally considered "conflict resources". This has the potential to further complicate future access; directly through supply shortages as a result of actual physical unavailability, as well indirectly through legal policy means.

Resources demand from large neighbouring economies, such as DRC, URT and Burundi admittedly places pressure on the potential Rwanda development mineral expansion. Coupled with increased commitment to infrastructure development by Tanzania, and the acceptance thereof, necessitates a possible reconsideration of the manner of Rwanda involvement in its own assistance and development mechanisms to emerging mining economies in the country.

As semi-gemstone minerals are nearly all produced for export, those on international markets (Chinese) lead prices in regional markets, (Jessica Elzea Kogel, *et al*, 2009). Regional markets, however, are highly imperfect and those for gems are quite volatile. Market information is so poor or imperfect in most places that there can be a significant time lag before international price changes and market conditions are reflected in local markets.

Rwanda is targeting to become an African hub and its current trade policies are designed to attract the mineral trade. Kigali is developing capacities in market information leadership, and has minimum ICT, financing and transportation costs in the region. Financial and ICT information systems are the two motors of a viable mineral trading network. Local Rwanda mineral and trade licence holders are mobilizing local resources to optimize value additions.

4. The Mining Sector Value Chain Model

Section 3 presents and discusses the development mining sector value chain model in Rwanda using the classical Michael Porter's (1979). The model is now modified by introducing the following major assumptions. Our model considers that the mining sector operates in a dynamic social economic system composing of [1] social economic entities, (SEE) or institutions, [2] social economic activities, (SEA) and [3] social economic sectors, (SES).

In turn, main social economic entities include individuals, households, families, communities, government (ministries, departments and agencies), private sector (firms, organizations and associations, non-governmental organizations, community based organisations, civil society organizations, cooperatives, and international organisations and entities. These are interrelated and legal institutions, dynamic and have different but not conflicting national interests.

The main social economic activities include investments, production, trade, distribution, consumption and savings. These are interdependent, dynamic and change with time and space.

The major social economic sectors are agriculture, industry and services. These are interdependent and dynamic. This model focuses on the role of industrialization for sustainable social economic development. The major industry sectors include [1] mining and quarry, [2] manufacturing, [3] building and construction, and [4] utilities consisting of water and energy systems. The development of mining and quarry is complex functions, transformations and dependents on the developments and transformations of the building, construction, utilities, agricultural and service sectors. The model assumes that social economic entities own, manage and operate social economic activities and sectors.

4.1.Mining System Operations

The mining policy model considers mining system functional objectives and operations to constitute six major interrelated and or interdependent social economic activities. These are [1] core mining activities, (C*M*) [2] environment and waste, (*E*) [3] occupational health and safety, (*OHS*) [4], Security; [5] corporate social responsibilities, and [6] Cross-Cutting (*CC*). These are treated as mining target policy variables, endogenously determined with the social economic system. The prevailing social economic system is composed of the current sector (e.g., national mining policy), macro-economic (e.g., national investment policies) and crosscutting policies, (national environment, occupational health and safety policies); laws and regulations and institutional frameworks. We formalize as follows;

$$1 \quad M = CM + E + OHS + S + CSR + CC$$

The standard core mining models relation (1) integrates environment and waste management activities. Environmental activities can include erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to create space for the storage of the created debris and soil. Contamination resulting from leakage of chemicals can also affect the health of the local population if not properly controlled

Mining companies in most countries are required to follow stringent environmental and rehabilitation policies, laws, regulations or codes in order to minimize environmental impact and avoid impacting human health. These codes and regulations all require the common steps of environment impact assessment, development of environment management plans, mine closure planning (which must be done before the start of mining operations), and environment monitoring during operation and after closure. However, in some areas, particularly in the developing world, government regulations may not be well enforced.

Ore mills generate large amounts of waste, *called tailing*. For example, 99 tons of waste are generated per ton of copper, with even higher ratios in gold mining – because only 5.3 g of gold is extracted per ton of ore, a ton of gold produces 200,000 tons of tailings. (As time goes on and richer deposits are exhausted – and technology improves to permit – this number is going down to .5 g and less). These tailings can be toxic. Tailings, which are usually produced as slurries are most commonly dumped into mining slurry ponds made from naturally existing valleys. These mining slurry ponds are secured by impoundments dams or embankments.

The waste is classified as either sterile or mineralized, with acid generating potential, and the movement and storage of this material forms a major part of the mine planning process. When the mineralized package is determined by an economic cut-off, the near-grade mineralized waste is usually dumped separately with regard to later treatment should market conditions change and it becomes economically viable. Civil engineering design parameters are used in the design of the waste dumps, and special conditions apply to high-rainfall areas and to seismically active areas. Waste dump designs must meet all regulatory requirements of the country in whose jurisdiction the mine is located. It is also common practice to rehabilitate dumps to an internationally acceptable standard, which in some cases means that higher standards than the local regulatory standard are applied.

4.2.None-Core Mining Systems and Operations

This theoretical policy paper starts with the core mining operational activities on strong assumption that environment and waste are cross sectoral mining policy issues that have their own and solid independent policies, laws, regulations and institutions. That is, the paper assumes that the core mining operational activities are our core mining policy objectives and therefore the focus and integrated environment and waste management activities must be well handled.

$$2 \qquad E = E^{*} \qquad E^{*} \ \ is \ \ at \ \ optimal \ \ conditions$$

This paper will not detail issues related with, environment, (*E*) occupational health and safety, (*OHS*) corporate social responsibilities, (*CSR*) and Cross-Cutting (*CC).* We will assume these are manageable and controlled at optimum and constant levels as follow;

$$\begin{aligned} OHS &= OHS^{*} \\ 3 \quad S &= S^{*} \\ CSR &= CSR^{*} \\ CC &= CC^{*} \end{aligned}$$

4.3.Core Mining Operational Stages, Phases and Activities

The paper defines and focuses on the core mining operational stages, phases and activities, (*M);* to include [*M1*] Mineral Deposits, [*M2*] Explorations, [*M3*] Extractions, [*M4*] Processing, [*M5*] Beneficiations, [*M6*] Trades and Marketing, and [*M7]* Final Consumptions by households. The model assessment defines these as core mining policy objectives and endogenous variables. The endogenous variable is a policy target variable in an assessment model that's changed or determined by its relationship with other variables within the model. In other words, an endogenous variable is synonymous with a dependent variable, meaning it correlates with other factors within the social economic system being assessed, (Alain Martel and Walid Klibi, 2016).

$$M = M^1 + M^2 + M^3 + M^4 + M^5 + M^6 + M^7 \quad (4)$$

Relation 4 is a simple linear equation and assumes that the value chain is a set of independent but interdependent mining operations, activities and companies that work closely together to identify, create, deliver and service customer value expectations. Also, the relation 4 suggests that our value chain analysis will extend across all development mineral operations, industries and organisations and it is useful to consider both when policy options are articulated, (Walters, 2002). For example amethyst mining firms from Rwanda have been searching opportunities for mineral market expansion either by identifying new product opportunities for existing customer markets in China, the possibility of extending the market coverage to new customer groups in Rwanda, or expanding delivery options by designing new final consumer product developments (e.g., as they become available and relevant. Value chain analysis also identifies sectors of the value chain that are underserved or which offer opportunities for improving value added contributions to participants by directing companies towards sectors of the value chain to which their competencies could be applied effectively. This can result in increased profitability and competitive advantage, (Walters, 2002).

The paper considers that at each stage there are inputs (inbound logistics), transformation processes, (operations) and outputs (outbound logistics), (Alain Martel and Walid Klibi, 2016). Also, given current economic, ICT and global network changes, we consider procurement and all services to be included and integrated in all the mining operations and activities required to keep the mineral products effective and efficient for the buyers after they are sold and delivered. Let us formalize these inputs and outputs policy variables as follows;

4.4.Physical, Virtual and Combined Value Chain

Competitive advantage cannot be understood by looking at a firm as a whole. It stems from the many discrete activities a firm performs in designing, producing, marketing, delivering and supporting its product, (Julia Connell, *et al*, 2018). Each of these interdependent activities can contribute to a firm's relative cost position and create a basis for differentiation.

$$M_{IN}^{i} \quad inputs$$

(5)

$$M_{OUT}^{i} \quad outputs$$

Let us now formalize mining operations as the management of the transformation process that converts inputs (in the forms of raw materials, labor, and energy) into outputs (in the form of products; goods and/or services), that is, first forms of value creations or additions, (David Walters, 2002). *We identify these first forms of value additions as the converted differences between the outputs (outbound logistics) and Inputs (inbound logistics), as follows;*

$$6 \qquad m_v^i = M_{OUT}^I - M_{IN}^I \qquad whereby \quad m_v^i \quad is \quad flow \quad \text{var}iable\, and \quad i = 1,2,...,7$$

We will consider that all social economic entities in the mining sector markets and operations are rational corporate entities thus have single objectives of minimizing costs and are profit maximizing operators, (Alain Martel and Walid Klibi, 2016). This paper adopts Rwandese definitions of value addition, (Republic of Rwanda, 2017a). In some cases, value addition is restricted and specifically linked to beneficiation entailing the transformation of a mineral (or a combination of minerals) to a higher value product, which can either be consumed locally or exported, (Department of Mineral Resources, 2011). Also, downstream value addition involves a range of activities including large-scale capital intensive activities such as smelting and refining as well as labour-intensive activities such as craft jewellery and metal fabrication such as machinery and equipment manufacture.

4.5.Exogenous or Policy Instrument Variables

In order to conduct assessment of the development mineral value chains and to provide policy options for enhancing the contribution of the sector to economic development, it is important to identify and determine important variables and relationships determining performances of mining operations at each particular stage and time. The performances of core mining operations and core mining policy variables are complex functions of interdependent endogenous (target variables); exogenous (policy instrument variables) and other external controlling variables.

In this policy assessment model, an exogenous variable is one whose value is determined outside the mining sector system and is imposed into the model, and a variable whose state is independent of the state of other variables in the social economic system. The exogenous factors are inputs into the system that are present and active in the mining operations but that originated and controlled by other forces, institutions, and powers and thus can be considered *as policy variable instruments*. Let us consider two types of exogenous variables.

The first categories are exogenous policy variables (*X*) which are outside the control of the mining sector firms or social economic entities but inside the control of the national social economic systems. Many policy models include systems (policies, laws, regulations and institutions, infrastructural and resources (human, capital equipment machineries, and technologies) as main exogenous factors.

The second categories are external exogenous policy variables (*Z*), which are outside the control of the country or nation or human beings. These include environment and climatic changes, global politics, trade, technological changes and wars.

4.6.Social economic welfare development

The assessment assumes that the overall and final objective of maximizing development minerals is to optimize current and future national (*W*) social economic welfare development. We consider social economic welfare development to include social, economic and wealth aspects.

The socioeconomic status is an economic and sociological combined total measure of a person's work experience and of an individual's or family's economic and social position in relation to others. When assessing national, family or individual social development categories, we can include income, wealth, education, health and occupation can be assessed.

Income refers to wages, salaries, profits, rents, gross domestic product (GDP) and any flow of earnings received at a particular point of time. Income can also come in the form of unemployment or worker's compensation, social security, pensions, interests or dividends, royalties, trusts, alimony, or other governmental, public, or family financial assistance. It can also come from monetary winnings, as from remittances or any form of external earnings.

Wealth, a set of macroeconomic reserves or assets, presents a source of security providing a measure of a household's ability to meet emergencies, absorb economic shocks, or provide the means to live comfortably. Wealth reflects intergenerational transitions as well as accumulation of income and savings. Income, age, marital status, family size, religion, occupation, and education are all predictors or factor variables for social economic wealth attainment.

Equation 6 has identified the development mineral value addition relational variable. We will now define development mineral value addition variable as a complex production transformation function of exogenous (inputs *X and Z*), endogenous variables (other core-interdependent mining operations) and other intermediating policy variables, (Social Economic Welfare, *W*);

$$7 \qquad m_v^i = m_i \ (\ X, \ Z, \ m_v^j \ W \ ) \qquad \text{where} \quad i \quad \text{and} \quad j = 1,2,...,7$$

We will focus and assess inputs (*X & Z*) and outputs (*m*) as measured in flow units: a certain amount of labor per week/month/year and a certain number of machine hours per week/month/year will produce a certain amount of output a week/month/year, (Alain Martel and Walid Klibi, 2016). Equation 7 considers that each development mining operation, activities, and firms have stakes in the success of the others. Each search for ways in which inputs (*X, Z*) can be utilised cost-effectively throughout the value chain'

We consider that the mining firms face fixed prices for its inputs and outputs and have a market where the individual producers take the prices as given and or determined in a competitive market system. Our assessment focuses on the profit maximization problem of a mining firm that faces competitive markets for the factors of production it uses and the output goods it produces

If the mining firms have made the optimal choices of all inputs (*X, Z*), the value of the marginal product of each factor should equal its mineral product market price and thus optimizes profits. The optimal development mineral values added for these firms are defined as;

$$8 \qquad m_v^{i*} = m_i \left(X^*, Z^*, m_v^{j*} W^* \right) \qquad \text{where } i \text{ and } j = 1,2,...,7$$

In the assessment, the observed and actual development mineral values added will not necessarily will be the same as desired or optimal levels, (Alain Martel and Walid Klibi, 2016). The actual development mineral values added for these firms will be;

$$9 \qquad m_v^{ia} = m_i \left(X^a, Z^a, m_v^{ja} W^a \right) \qquad \text{where } i \text{ and } j = 1,2,...,7$$

Above equations 7, 8 and 9 introduce elements of firm linkages or networks. The firm's linkages are used here in a metamophorical sense and refer to the aggregated pattern of inter-unit relationships in the social economic systems. The relations suggest that to increase and keep the value of Rwanda development mineral resources it requires the creation and strengthening of linkages between the extractive sector, manufacturing and other sectors of the economy. These linkages include: down-stream (or forward) linkages into mineral beneficiation and manufacturing; up-stream (or backward) linkages into mining capital goods, consumables and services industries; spatial linkages into infrastructure, such as power, logistics and technological development, (Uongozi Institute, 2017).

The assumption is that links or bonds between various social economic actors in the social economic systems, such as suppliers of inputs, producers, traders, customers and their supporting institutions may be viewed as a structure that can be perceived as a network, (Alain Martel and Walid Klibi, 2016). Most industrial units are rooted in a socio-cultural, technical, and economic environment of more or less stable relationships to other actors, (Jose, 1994). Furthermore, it is assumed that the advancement of technological capability may be comprehended as interactive technical processes. Knowledge and skills are also created, adopted, modified and developed as an outcome of the linkages one firm develops/is able to develop with other firms.

During social economic production a firm or a unit is interacting to create a niche (or an environment) for its survival, growth and development. The industry environment, from the perspective of a single company, may be viewed in terms of its network which is basically the set of companies and organizations with which the single firm interacts. The industry relationships are the results of continuous interactions between the actors, which comprise activities such as buying and selling of input supplies, investments, production processes, trade, exports, imports, consumption, subcontracting arrangements and technical consultancies by external companies.

Mining firms build up relationships with one another to gain access to input and output markets or exchange resources such as capital, personnel, technology, materials and information, (Alain Martel and Walid Klibi, 2016). These relationships reduce transaction costs connected to uncertainty, bounded rationality, small numbers, and information impact and asset specificity. Since the relationships are of a dynamic nature, they also become important structural determinants, contributing to structural change, source of innovation and inducing industrial advancement. In so doing, companies form sustainable industrial systems.

The essential point about a social economic system is that it allows technical, market and social efficiency which single industrial units can rarely attain. A set of producers making the same product in close cooperation constitute a viable industrial system. Over time, these kinds of linkages constitute a major facilitating factor for sustainable industrial development.

We now identify and *define the second levels or forms of value additions as the differences between the desired or optimal development mineral values added and the observed and actual development mineral values added.* The firms create more value additions when they move from non-optimal positions to desired optimal development mineral values added during transformation processes.

$$10 \qquad mm_v^i = m_v^{i*} - m_v^{ia} \qquad whereby \qquad i = 1,2,.....,7 \qquad mm_v^i = more\ \ value - additions$$

5. Paper Findings: Policy Model Solutions, Options and Targets

The above presented equations 1 – 10 articulate a structural policy theoretical model to be used to make an assessment of the development mineral value chains in Rwanda. This is a dynamic policy model as it includes stocks and flow endogenous and exogenous variable levels at each particular of time and changes technologies. *The paper finds that the first level target development mineral values added variables are defined as;*

$$11 \qquad m_v^{i\wedge} = m_i \ (\ X^\wedge, \ Z^\wedge, \ m_v^j \ \ W^\wedge \ ) \qquad where \ \ i \ \ and \ \ j = 1,2,...,7$$

That is, the reduced form policy theoretical model is determined upon substituting vales of equations 8 and 9 into equation 11.

Also, *the paper finds that the target second levels or forms of value additions for development mineral values added;*

$$12 \qquad mm_v^\wedge = m_i \ (\ X^\wedge, \ Z^\wedge, \ m_v^{j\wedge} \ W^\wedge \ ) \qquad where \ \ i \ \ and \ \ j = 1,2,...,7 \qquad mm_v^\wedge \ \ are \ \ policy \ \ target \ \ options$$

Equations 11 and 12 articulate and summarize potential policy options for the first and second levels or forms of development mineral value additions enhancing the contributions of the development mineral sector to economic development, (Alain Martel and Walid Klibi, 2016). Equations 11 and 12 will assist in searching, designing and formulating appropriate policy objectives, strategies and actions to options to solve them, articulating the options clearly. Based on above findings in terms of relations and assumptions in equations, 1, 2, and 3 we will be able to finally decide upon which of the policy options to take, implementing the strategic policy options, monitor, controlling and finally evaluating the implementation processes.

The policy solution emphasizes the importance of strengthening all mineral-based linkages while resources are extant so as to maximize the developmental and inter-generational impact of those resources. This is the current, operational and consistent meaning of value addition in the mining sector. If managed appropriately, resource-based investments can lay the foundation for

diversified economies. Conversely, if African countries cannot make these linkages then it would be best to leave the resources unexploited until such time that the linkages can be made, (Uongozi Institute, 2017)

The nation's mining policy objective is to target sustainable development of development minerals, (*M*). Targeting *M i*s a complex function of targeting Mineral Deposits, [*M1*]; Explorations, [*M2*]; Extractions, [*M3*]; Processing, [*M4*] Beneficiations, [*M5*] Trades and Marketing, [*M6*] and Final Consumptions by social economic entities such as households, firms and communities, [*M7]*.

The policy findings and solution is target sustainable development of development minerals, (M) by emphasizing the importance of strengthening all optimal mineral-based linkages while resources are extant so as to maximize the developmental and inter-generational impact of those resources. The nation's mining policy objective is to ensure efficient and effective utilization of Mineral Deposits, [*M1*]; Explorations, [*M2*]; Extractions, [*M3*]; Processing, [*M4*] Beneficiations, [*M5*] Trades and Marketing, [*M6*] and Final Consumptions by social economic entities such as households, firms and communities, [*M7]*. *This is formalized as follows*;

13 $M^{\wedge} = M^{1\wedge} + M^{2\wedge} + M^{3\wedge} + M^{4\wedge} + M^{5\wedge} + M^{6\wedge} + M^{7\wedge}$ *where*$--$ $M^{i\wedge}$ *are policy tarrgets*

Table 2: Outline of the Proposed National Mining Policy Format

Main National Mining Policy Objectives		
Core Mining Policy Objectives		***Policy Strategies***
1	Mineral Deposits, [*M1*];	*Xi, Zi, mi, and W*
2	Explorations, [*M2*];	*Xi, Zi, mi, and W*
3	Extractions, [*M3*];	*Xi, Zi, mi, and W*
4	Processing, [*M4*];	*Xi, Zi, mi, and W*
5	Beneficiations, [*M5*];	*Xi, Zi, mi, and W*
6	Trades and Marketing, [*M6*]	*Xi, Zi, mi, and W*
7	Final Consumptions [*M7]*	*Xi, Zi, mi, and W*
8	Environment, (E)	*Xi, Zi, mi, and W*
Other Mining Policy Issues		***Policy Strategies***
9	Occupational Health and Safety, (OHS)	*Xi, Zi, mi, and W*
10	Corporate Social Responsibilities, (CSR)	*Xi, Zi, mi, and W*
11	Cross-Cutting Issues, (CCI): These may include; *Gender*, *Child Labour* *Youth Participation*	*Xi, Zi, mi, and W*

Table 2 summarizes an outline of the proposed national mining policy format based on above model relations 1- 13. Table 2 and relation 13 proposes the need to identify the development mineral policy objectives, options and decisions required in the value chain and the processes that are necessary to make them effective and efficient, in other words the strategic and operational features of the value chain, (Walters, 2002). Table 2 suggests the need to identify, list and sequence these national mining policy objectives based or founded on the best practices, value chain model and mining sector sciences and principles.

6. Conclusion Rwanda National Mining Policy System

The paper made an assessment on the current status of development mineral value chains; presented and discussed classical Michael Porter's (1979) value chain model articulating full range of development mining activities in Rwanda, and proposed consistent recommendations on policy options and other incentives necessary to enhance the contribution of the mining sector and their value chains to sustainable social economic development.

Table 2: Outline of the Proposed National Mining Policy Format

Main National Mining Policy Objectives		
Core Mining Policy Objectives		***Policy Strategies***
1	Mineral Deposits, [*M1*];	*Xi, Zi, mi, and W*
2	Explorations, [*M2*];	*Xi, Zi, mi, and W*
3	Extractions, [*M3*];	*Xi, Zi, mi, and W*
4	Processing, [*M4*];	*Xi, Zi, mi, and W*
5	Beneficiations, [*M5*];	*Xi, Zi, mi, and W*
6	Trades and Marketing, [*M6*]	*Xi, Zi, mi, and W*
7	Final Consumptions [*M7]*	*Xi, Zi, mi, and W*
8	Environment, (E)	*Xi, Zi, mi, and W*
Other Mining Policy Issues		***Policy Strategies***
9	Occupational Health and Safety, (OHS)	*Xi, Zi, mi, and W*
10	Corporate Social Responsibilities, (CSR)	*Xi, Zi, mi, and W*
11	Cross-Cutting Issues, (CCI): These may include; *Gender,* *Child Labour* *Youth Participation*	*Xi, Zi, mi, and W*

The paper recommends the Rwanda government ministries, departments, agencies and development mining value chain companies to be concerned with the level of success of each of the other social economic entities. All social economic entities have to share a common goal of achieving profitability, productivity and optimal cash flow for the entire development mineral value chain. It follows that national development mineral operations management, implemented

through value chain management, requires a new, operational and different perspective of relationship management, (Alain Martel and Walid Klibi, 2016).

Rwanda has to develop and achieve the "transparent, equitable and optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development", (Uongozi Institute, 2017). This Rwanda ability to see beyond corporate boundaries permits recognition of serious global development mineral markets and trade threats that lie elsewhere within the value chain as well as the chance to pursue opportunities that would otherwise be missed. For example, the value chain in the amethyst encourages expertise and specialization and all this implies optimal utilizations of systems, resources, infrastructure facilities, organisation structures, private and public management relationships

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