

*Full Length Research Paper*

# Potential of artisanal and small-scale gold mines for economic development in Tanzania: A review

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The availability of mineral deposits for many decades provides an avenue for improving the economic development of the local artisanal and small scale miners in Tanzania. This study documents different possible locations from various available data and show the characteristics of the existing gold deposits extracted and processed by the artisanal and miners using ArcGIS software. It identifies the challenges of utilizing the obsolete equipments, lack of skills and knowledge of mining and mineral processing operations, and improper negotiation between primary mining license owners (PML) and pit holders based on mine plan and design, safety, and environmental management in different artisanal and small-scale Mines (ASMs). However the conceptual model of ASM based on the secondary data gathered was well developed, as well as discussions on the digging, loading and transportation, crushing and mineral processing operations of the existing ASMs. Therefore, the author recommends the documented information in this study as significant in promoting and facilitating further research in Tanzania's ASM field.

**Key words:** Artisanal and small scale miners, Artisanal and Small-scale Mine (ASM) model, challenge, economic situation.

## INTRODUCTION

Tanzania is among countries having abundant mineral resources including gold, diamonds and a variety of colored gemstones like tanzanite, ruby, garnets, pearl, etc, with several major and junior companies exploring and producing gold, mostly in north western Tanzania, south of Lake Victoria, in an area informally known as the Lake Victoria gold belt to central part, and southern part of Tanzania (URT, 1997).

Currently, both artisanal and small scale miners have increased the interest of searching and acquiring minerals for increasing their revenue base. Small scale

mines provide employment for an estimated 13 million people in developing countries (ILO, 1999). The number of artisanal and small scale miners in Tanzania ranges from 500,000 to 1.5 million (Carstens et al., 2009). The ASM can be defined as small groups of people engaged in predominantly simplified forms of exploration, extraction, processing and transportation with low cost, low technology and labor intensive methods. Thousands of artisanal and small scale miners have engaged in a complex and arduous mining operation with hammers, picks and torches in high depth and narrow pits, and

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pound large chunks of rocks into smaller pieces traditionally for amalgamating processes (Bryceson and Jonsson, 2012).

The average contribution of the mining sector in Tanzania's economic growth was gradually increased from 0.2% in 1995 - 1999 to 3.4% in 2007 - 2008 (URT, 2008). According to UNEP (2012), ASM gold mining may account for approximately 10% of Tanzanian gold production. Still Mwakaje (2012) indicated most of the artisanal and small scale miners operate without Primary Prospecting License (PPL) and Primary Mining License (PML) which mostly are associated with risky environments. In fact, most of the mining companies were nationalized after the Arusha Declaration in 1967 which was transformed by the Tanzania's government to Tanzania Gemstone Industries Company (TGI) in 1972, with monopoly in mining producing and purchasing power.

Still there is a Mwadui Community Diamond Partnership (MCDP) with partners including DeBeers, Williamson Diamond Limited, and the United Republic of Tanzania represented at national, regional, district and local levels, which engaged in mining operations. The formation of State Mining Corporation (STAMICO) in 1973, which had the responsibility of administering the development of small scale mines, including geological investigations, facilitation and dissemination of technologies in mining and mineral processing, and fasten the accessibility of financial institutions, and centralized mineral markets and trends (URT, 1992), makes the significant difference in ASMs development in Tanzania.

Mining operations under ASMs are conducted by digging unstable pits, blasted with weak explosives, transported with heavy bags of broken ore to the settlement area. The fragmented rock are ground into powder form and mixed with water and mercury to attract gold particles. The mixture of mercury and gold are burnt to evaporate the mercury and recover the gold. Still other small scale miners recover gold by using under water gravitational mechanisms.

Equipments used for mining and mineral extraction can be differentiated between those whose operations are purely manual, like those utilized in ASMs and those that have introduced some advanced technology which utilize hydraulic or electronic mechanisms which are mostly used in large scale mines. These advanced technological equipments include drilling and blasting machines, dump trucks, grader, excavators / scoop / loader, generator, sluice box with vibrator, crusher and grinding machines. Additionally, there is a possibility to use other methods of processing mineral such as advanced gravity and magnetic separation, froth flotation and leaching processes. This study therefore, utilized the available research reports and analyzed different locations of the ASMs with their model of operation and challenges to evaluate its potential for economical development in Tanzania.

## MATERIALS AND METHODS

### Location of the study

Tanzania is located in the eastern part of the African continent, south of the equator. It lies between the area of the great lakes – Victoria (Northern), Tanganyika (Western) and Nyasa (South-Western) – and the Indian Ocean (Eastern) as indicated in Figure 1. Tanzania has a total area of 945,087 km<sup>2</sup> including 59,050 km<sup>2</sup> of inland water. The map in Figure 1 also indicates the nature and locations of the small scale gold mining sector in Tanzania (Masanja, 2012; URT, 2013) where most of the artisanal and small scale miners extract gold deposit.

### Nature of the artisanal and miners in Tanzania

The potential for economic mineralization is widely recognized at over 800,000 km<sup>2</sup> in Tanzania (URT, 1997). Gold mineralization is concentrated in Lake Victoria greenstone belts such as the North-Western region up to Mpanda, Lupa mineral fields and Western part of Tanzania in the Ubendian system. Diamond occupy more than 300 kimberlite pipes which extends from Mwanza through Shinyanga to Tabora and Singida, and proterozoic coloured gemstones in Usagarian and Ubendian system of central and western part of Tanzania. Small scale mines are mostly operated with minimal coal resources in Karoo system (URT, 1997). The nature and extent of the growth of artisanal and small-scale mining operations in Tanzania is influenced both by geological settings of the mineralization, socio-economic structures and traditions.

Figure 2 summarizes the number of artisanal and small scale miners' change and percentage growth of the mining sectors from 2000 to 2010 (Carstens et al., 2009; Dreschler, 2001; URT, 2010). Although the author noted the lack of data during analysis, still the percentage growth of the mining sectors indicates a tremendous decrease from 10.7% in 2007 to 2.8% in 2011. However, the number of artisanal and small scale miners increased gradually from 29% in 2010 to 43.5% in 2014 with the range of 1 - 1.5 million of the population engaged in mining operations. Most of the artisanal and small scale miners are engaged in ASMs to improve their standard of living.

### Data analysis

Although the data collected are few, one could see that based on the map presented in Figure 3, about seventy five percent (75%) of Tanzania land is covered. Besides, the data coverage represents a wide range of gold mineralization utilized by the ASMs and well documented with help of ArcGIS software. The software helps to interact and indicate different artisanal and miners points and offer the digitization process to develop overall ASM map. Necessary research reports were collected, analyzed and a model developed, of the way artisanal and small scale miners carry out their daily activities. The study utilized a fish bone diagram concept to summarize all factors associated in ASMs operations, which if properly handled could increase their socio-economical situation.

## RESULTS AND DISCUSSION

### Possible locations of ASM for gold operation in Tanzania

Different centers in Tanzania with potential of ASMs were documented (Bryceson and Jonsson, 2012; Dreschler,

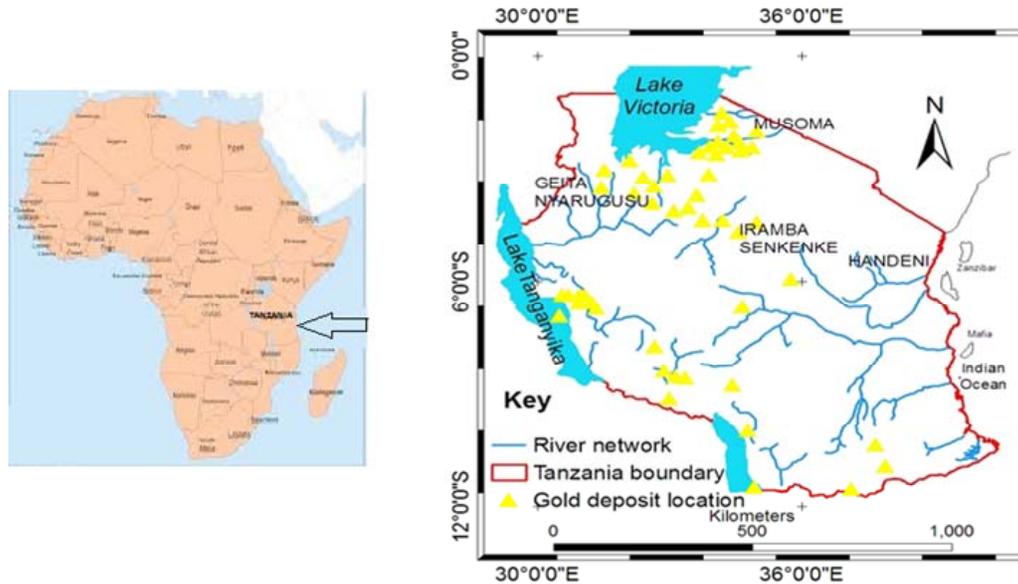


Figure 1. Location and gold deposits of the study area.

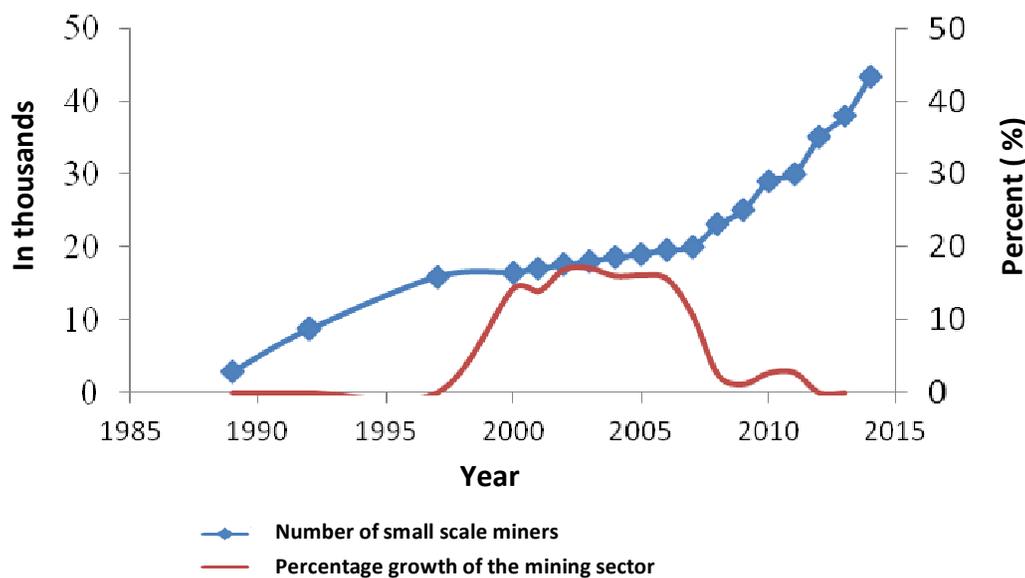


Figure 2. Artisanal and miners with percentage growth of the mining sector in Tanzania.

2001; HRW, 2013; CRI, 2011; Howard, 2011; URT, 1998). There are 76 known and audited ASMs at different gold deposits; 51 gold processing sites that are randomly distributed within Tanzania (URT, 1998) and presented in Figure 3. This summary of all potential centers from different researchers for various ASMs in Tanzania was compiled under ArcGIS software 9.3 version. The main mining activities conducted in each identified location include drilling, blasting, loading, haulage/hoisting and mineral processing.

### Operational situation of ASM

The ASMs in Tanzania operated at two hierarchical orders are marked with “point 1” and “dotted lines” as indicated in Figure 4. The PML owners of the small scale mines has the right to operate mining activities and the responsibility of hiring and compensating labour, purchasing mining and mineral processing equipments, adherence to safety and environmental regulations as shown in “Point 1”. On the contrary, the PML owner hired

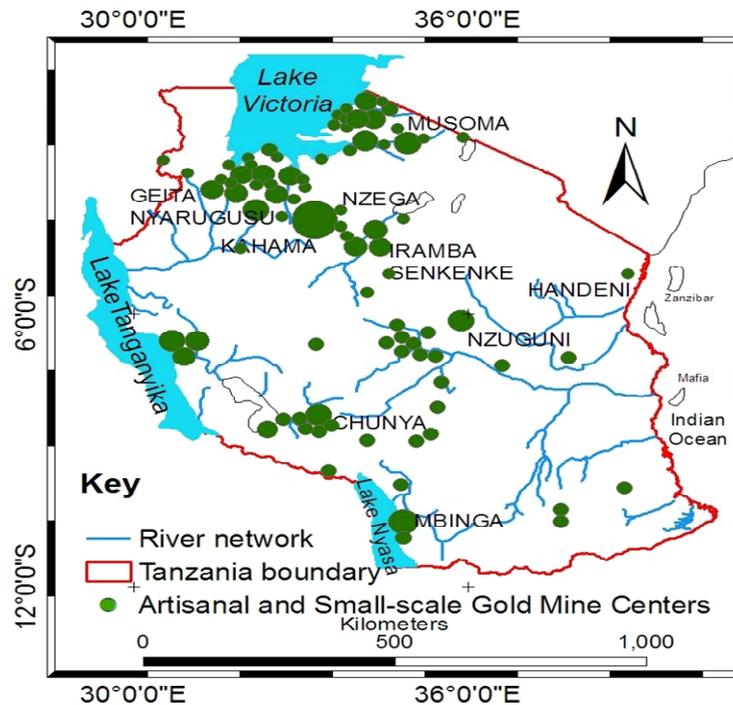


Figure 3. Distribution of small scale gold mining centers in Tanzania.

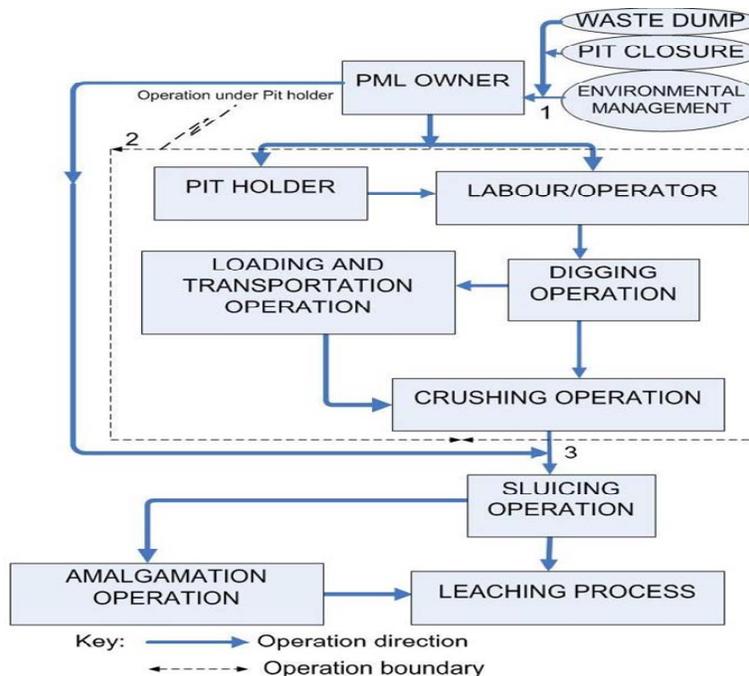


Figure 4. ASM conceptual model of operation.

a Pit holder and gives him the responsibility to organize procurement and sourcing of all necessary day to day mining activities and administering the number of labors

(Bryceson and Jonsson, 2012; URT, 2010; URT, 2013). The Pit holder managed all labours under drilling and blasting, material loading and transportation operations

as indicated with dotted line 2. Capital investments and costs related to fruitless periods fall upon pit owners who are the primary financial risk-takers. However the division of gold bearing rocks varies but in most places the rule of thumb is 30% PML, 40% pit holder and 30% divided amongst the labors (Bryceson and Jonsson, 2012; CRI, 2011) and presented in “point 3” when the PML owner targets to return the incurred cost of attaining mine license.

### Key challenges

Although ASMs are important sub-sector in Tanzania, artisanal and miners are usually still carrying operations with weak technology, such as traditional hand tools and processing equipments (Dreschler, 2001). The lack of modern technological equipments causes small scale mines in some special consideration to dig up to 25 meters and then stop due to the challenge of shaft support materials, dewatering system, increase of rock hardness and ventilation mechanisms. Other key challenges include the following:

(1) Informal or illegal status between PML owners and pit owners and operators: Lack of knowledge and skills of negotiation between PML owners and Pit holders based on the mining operation without regarding the waste dump management, pit closure cost and environmental issues results in improper mining practices. Lack of Pit owner investment capital, typically restricts production to basic and traditional processes and often results in debt bondage and poverty traps with poor mineral recovery below 40% (Dreschler, 2001). A number of pits are left after digging operations without following proper mining closure procedures due to the fact that the PML owners of the mine area are responsible for taking such measures and not the one who operate at the mines, resulting in poor environmental management and safety practices in general (Bryceson and Jonsson, 2012).

(2) Local to large scale mines: The limited local employment in mining investment is partly due to the capital-intensive nature of production in large scale mines which include the Anglogold Ashanti in Geita Region; Barrick Gold Company in Tarime and Kahama Districts; Williamson Diamonds Company in Mwadui-Shinyanga, TanzaniteOne in Mererani, Arusha Region. Recruitment process mostly takes place outside the locality, largely in the commercial capital like in Dar es Salaam; and outsourcing from countries of skilled mining labour such as South Africa, Australia, Canada, Ghana and Namibia (Kweka, 2009).

Exploitation of mine labours in ASMs includes work with women and migrants, and use of child labours who mostly are drop-outs from schools (HRW, 2013; Kinabo, 2006). However the increased number of local miners, children and women presented in Figure 2, in mining and

working with mineral processing tools are influenced by the existing gold mineralization within the study area.

(3) Material Handling: Digging operation is conducted from the surface by digging deep and narrow pits parallel to ore zones utilizing hammer, pick and torches. The digging holes are blasted with low energy explosives to acquire the crushed rocks. Loading operation of crushed ore and waste is carried out simultaneously at different locations in the pit with spades and bags. Sometimes, the Pit holder manages to hire a loader but is faced with the challenge of unsatisfactory digging conditions, truck capacity and utilization. Hauling materials from the loading area to the dump sites must be accomplished through a network of haul roads of various length and grades. Haul roads can be extremely complex, cover large surface areas and pass through extreme topographic undulation in ASMs. However the role of haul trucks in many mines is restricted with operation cycle between the loading zone and the dumping point such as in pit faces, crushing station or conveyance system (Hartman, 1992). Whereas in most small scale areas, crushed materials has been loaded into sacks and moved manually by mine workers (Mwaipopo et al., 2004). Few small scale mines remove all crushed rocks to a processing point either by bicycles or light vehicles.

Artisanal and small scale miners work without personal protective equipments to protect their hands, eyes, ears, feet and respiratory organs as the basic part of the human body to be equipped with safety devices. The situation is very difficult for drillers who most of the time works with jackhammer machines without pressure gauge, temperature gauge and safety valve to release excess pressure. Still there is the harmful fume from diesel engines. Shot firing produces fumes containing toxic gases especially sulphur dioxide and nitrous oxide, which when inhaled can lead to serious health conditions (Bratveit et al., 2003; Walle and Jennings, 2001).

(4) Amalgamation process: The crushed materials were reduced to obtain the required size by firstly using hammers and other metallic objects (HRW, 2013), and then subjected to local ball mill machine for crushing to powder fractions. The miners pour water over the powder and pass it through a sluice box. The sluice box is typically lined with sisal sacks or other materials that capture gold particles. The pit holders then rinse the accumulated particles out of the sacks into a pan or barrel to recover the concentration.

The concentration is subjected to pan with mercury in order to separate gold from the remaining dirt and other minerals and the process named amalgamation. Miners burn the amalgam to evaporate the mercury associated with toxic fumes and recover the gold. The remaining wastes are collected to undergo leaching process under the application of cyanide chemical. The author identified the challenge of artisanal and small scale miners to recover gold using mercury with their bare hands and burned in open air within the home or in processing

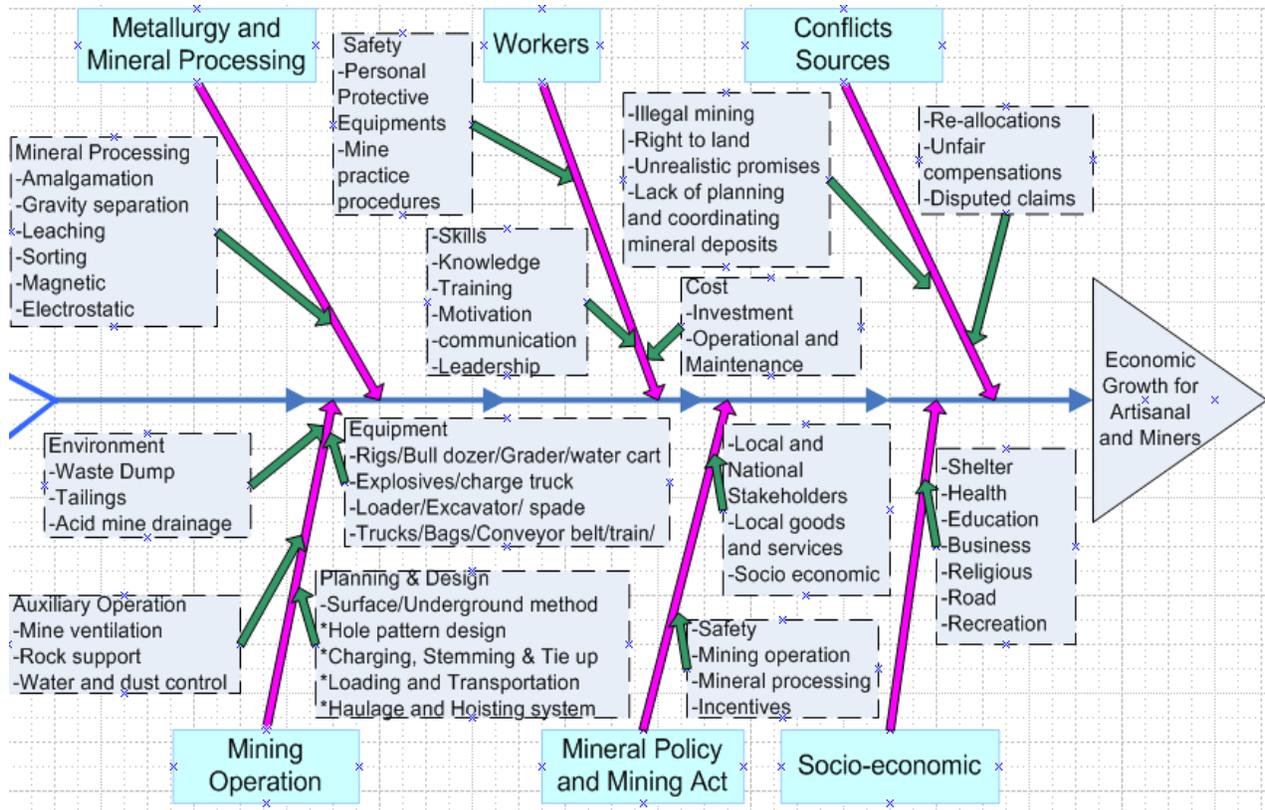


Figure 5. Fish bone diagram for economical growth for artisanal and miners.

areas. ASMs prefer mercury during gold recover over other forms of extraction because of its ease; affordability and accessibility with complain of the high cost of purchasing mercury-free extraction alternatives (Mwakaje, 2012; HRW, 2013).

**Potential of ASM in Tanzania**

Tanzania’s mining activity is regulated by the law relating to prospects for minerals, operation of exploration, mining and mineral processing; and dealing with miners to grant, renew and terminate mineral rights, payment of fees and other charges, royalties and any other relevant issues (URT, 2010a). The mineral policy of Tanzania, states the availability of minerals contribute significantly to the acceleration of socio-economic development through sustainable development (URT, 2009).

The socio-economic development includes sourcing of food, shelter or other materials locally rather than importing it; providing employment to youth, and supporting the development of local entrepreneurs and businesses that can serve the needs of the local communities. The ministry of Energy and Minerals started to grant the artisanal and miners with supervision of the

STAMICO that will provide technical assistance to strengthen the provision of extension services, like helping and facilitating various feasibility studies in ASMs. The documentation of the different locations and existing gold deposits provided the usefulness of the gold mineralization in Tanzania as presented in Figures 2 and 3.

Fortunately different studies indicate the areas with ASMs operation are more developed compared to other local areas engaged with only agricultural activities (Kinabo, 2006). Notwithstanding, there is a potential of miners to re-work tailings which have been left behind which no longer require mining operation by using leaching processes. The leaching process uses lower grade materials which were deemed uneconomical for the former operation, or uses river streams which contain alluvial gold downstream deposit. However, through engaging with ASM prior to closure, and involving the miners in the closure planning process, it may be possible to identify innovative approaches to manage the environment that benefit both the local communities and the nation at large.

The fishbone diagram presents the graphical way of organizing and managing the relationship between artisanal, miners and all associated factors that contribute to economical development. It focuses on specific issues,

identifies the areas where there is a lack of data and determines the basic reason in different factors that faces the artisanal and miners (Ishikawa, 1982). The main factors include the mining operation, metallurgy processing, mineral policy and mining act, workers, socio-economic and conflict sources. Therefore the study identified and presented sub-factors based on the main factors in Figure 5.

However, based on the main factors and sub-factors identified in this study, there are five specific technical concerns as future suggestions that can stimulate the artisanal and small scale miners, their economic growth, such as reinforcing the government based on the existing mining law to allocate the land for ASM areas with reduction in the cost of acquiring exploration and mining licenses; researching more on why the PML owners were not handling the mining operation and leaving it to pit holders; making cost analysis in mining equipments which are available easily in the world markets, as well as reducing operation and maintenance cost. Government through specific banks can provide financial support with an interest rate of less than 10% and providing capacity building training to artisanal and small scale miners based on the mining and mineral processing operations.

## CONCLUSIONS AND RECOMMENDATIONS

The elementary technology employed in small scale mines results in low rates of recovery and inappropriate market condition that in turn cause inability for most miners to invest in appropriate technology. Possible locations of gold deposits attracted to ASMs which can lead to difficult situation for new investors. The challenge of utilizing obsolete equipments, skills and knowledge of mining and mineral processing, existing conflicts of land right, unrealistic promises, unfair re-allocation and the lack of prioritization of available revenue are the key challenges to be eradicated to alleviate the problem in artisanal and miners' economic situation.

The issue of PML owner and pit holder, mine plan and design, mining safety, and environmental management can be major areas for further research and improvement based on the conceptual ASM model of the existing ASMs in Tanzania. Children and women engaging in ASMs with minimum application of personal protective measures which resulted in increased number of unhealthy women and children in communities. However, this study can be useful to investors, local entrepreneurs and suppliers to facilitate the ASMs in Tanzania. It also provides information to local communities and trade associations for further research in Tanzania's ASM areas.

## Conflict of Interest

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENT

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