PREDICTION OF CREDITWORTHINESS OF A VIABLE ARTISANAL AND SMALL-SCALE MINING OPERATION

By

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PhD

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Department of Mining Engineering

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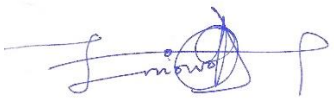

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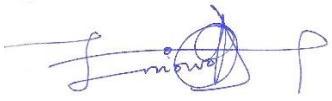

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Abstract

Prediction of Creditworthiness of a Viable Artisanal and Small-scale Mining Operation

O.D. ENIOWO

The purpose of this study is to formulate models for the prediction of creditworthiness of a viable Artisanal and Small-scale Mining (ASM) operation. ASM is a form of mining carried out by mostly informal miners using minimal mechanisation, which affects their level of output and productivity. The use of inefficient tools for extraction and processing also lead to safety, health and environmental hazards. In order reduce the negative tendencies of ASM and still enhance its productivity, formalising and upgrading the operations to a more responsible form of small-scale mining has been recommended by previous studies. However, formal lenders, such as banks, perceive ASM operations as very risky ventures and so they usually avoid investing in such operations. Consequently, the miners have had to settle for informal sources of financing and interventions from governments and international donors. However, these types of funding are usually short-lived, and do not always align with a business-led approach to developing sustainable long-term solutions. There is therefore a need for ASMs to be able access formal sources of funding. This problem necessitates the formulation of models that could assist a formal lender or an accounting officer of a formalised ASM operation to assess the viability of the operations for the purpose of accessing formal lending.

In order to achieve the aim of the study, a mixed form of research was carried out involving qualitative and quantitative research. A selective survey design was adopted for the study and Southwest Nigeria was selected for the research owing to the region's richness in all the mineral categories usually targeted by ASM operators. The government ministry that regulates ASM was contacted with a view to obtain a list of ASM cooperatives and associations. The heads of these cooperatives and associations were then interviewed to provide their perspectives on the credit constraints in the industry. Also, a formal lender, which is a government-owned development finance bank (Nigeria Bank of Industry, BOI) that lends to ASM operations was contacted for qualitative study. The aim is to acquire the bank's parameters for estimating creditworthiness of a competent loan application from an ASM borrower. The major parameters include: the licensing status of the operation; availability of loan guarantee in form of physical collateral or a guarantor to stand as surety; ability to afford the bank's interest rate; membership of the mine operator in a registered cooperative society; availability of feasibility study report; and availability of ore reserve

estimate. Based on the parameters obtained from the bank, a well-structured questionnaire was developed and was used to conduct quantitative research on a sample of 100 ASM respondents (one respondent per operation). Analysis of the research data was done using R programming language on RStudio which helped to develop simple and multiple regression models for creditworthiness of a viable ASM operation. The key findings from the study were duly presented based on descriptive and inferential statistics. The study recommends among others that future study direction should consider modifying, scaling, and improving available models for proving the viability of ASM operations.

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CHAPTER 1 INTRODUCTION

This chapter introduces Artisanal and Small-Scale Mining (ASM). It provides a background on the ASM industry and identifies its potential as a means of employment, especially for rural dwellers It examines the challenges facing the industry with a focus on credit access. It discusses access to funding in ASM, how small-scale mining is being funded, and the positives and drawbacks associated with each funding mechanism. Once these concepts have been defined, the statement of the problem of the study and the research questions are outlined. Lastly, the methodology adopted for the study is presented.

1.1 Background to Artisanal and Small-Scale Mining (ASM)

Artisanal and Small-Scale Mining (ASM) refers to the form of mining carried out by individuals, groups, families, or cooperatives with minimal or no mechanisation, often in the informal sector of the market (Hentschel, Hruschka, & Priester, 2003). ASM is low-tech, dangerous, and labor-intensive mineral extraction and processing (Hilson, 2003; Hilson & McQuilken, 2014). The major characteristics of the Artisanal and Small-Scale Mining (ASM) industry include the lack or very reduced degree of mechanization; a great amount of physically demanding work; low level of occupational safety and health care; and deficiencies in qualifications of the personnel at all levels of the operations.

Other characteristics of ASM include inefficiency in the exploitation and processing of the mineral production (low tonnage and grade recovery); exploitation of marginal and/or very small deposits, which may not be economically exploitable by mechanized mining; low levels of productivity; low levels of salaries and incomes; periodic operations by local peasants which are sometimes inspired by temporary higher market prices; lack of social

security; insufficient consideration of environmental issues; lack of working and investment capital; and mostly working without legal mining titles (Hentschel et al., 2003).

This background to ASM discusses the relevance of the occupation in developing countries. It then provides a legal code perspective of ASM. This section also provides the different forms of ASM practice and the various ways of classifying or categorising the occupation.

1.1.1 Relevance of the ASM Industry

The significant role played by ASMs in developing countries have long been identified (Noetstaller, 1987). The economic importance of small-scale enterprise stems from the fact that, generally, it is more labor-intensive than large-scale firms and therefore accounts for more recorded employments. It is equally true in rural communities where opportunities are particularly scarce (Noetstaller, 1987). In fact, according to Yankson and Gough (2019), local economies are primarily sustained by ASM and not Large-Scale Mining companies (LSM), because ASM provides employment and an alternative means of livelihood for local community dwellers. The activities also create other small businesses around the mining sites adding to a source of livelihood for villagers around the mining operations. Examples of these businesses are local food vendors and other merchants who sell products that may be needed by the miners working on the mine sites (Oramah, Richards, Summers, Garvin, & McGee, 2015).

The mining industry plays a key role in opening remote areas to industrial development. According to Sumi and Thomsen (2001), mine development brings with it the promise of other significant benefits. These include, for example, the creation of jobs, the creation of power infrastructure, transportation networks and increases the tax base, and other revenues generation activities to r the states and national government. Hence, ASM particularly can alleviate significant rural hardship, catalyse the growth of infrastructure, and

reduce rural-urban migration (Hilson & McQuilken, 2014). As such, ASM activities play a key role in reducing poverty in rural communities.

A recent estimate shows that as at 2017, globally, about 40.5 million people were believed to be working in ASM (Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development, IGF, 2018). This figure rose from 30 million in the year 2014, 13 million in 1999 and 6 million in 1993 (IGF, 2018). In the literature, there are different views on the causes of the recent proliferation of ASM globally: they include deep ancestral ties (Banchirigah, 2008); farming seasonality (Hison & Garforth, 2012); poverty (Hilson, 2012); entrepreneurial drive (or “get rich quick”) (Cartier, 2009); and mineral rush (e.g. “gold rush”) (Maconachie & Binns, 2007). Other studies assert that the recent proliferation of ASM is due to the rising value of mineral prices and difficulties in obtaining earnings from alternative livelihood such as agriculture and other rural activities.

However, on the technical side, some factors make ASM attractive. These include lower labour and technical costs, exploitation of deposits in lower volumes that is easily afforded, and exploring sites that are difficult to access by large mining companies, especially where there is a lack of transport infrastructure. Such deposits are better suited for ASM operations (Geenen & Radley, 2014). These factors create a competitive advantage for ASM over large-scale mining and a space for the practice of artisanal mining activities in the mining industry..

In some developing countries, artisanal mining operation constitutes the largest chunk of the country’s mining activities. As an illustration, ASM constitutes an estimated 95% of the entire mining industry in Nigeria. The gemstone mining sector in the country is exclusively controlled by ASM. Large-scale mining in Nigeria is limited to aggregate rocks, iron ore, and coal mining (Oramah et al., 2015; Eniowo et al., 2022). ASM plays a major role in

contributing to rural development in Nigeria. Specifically, it has immense socioeconomic significance in Nigeria - a nation having a population of 186 million people, 64% of whom reside in rural areas (Adesugba, 2018).

Consequently, ASM has experienced immense global growth in recent years. The occupation directly employs 40.5 million people in 2017, growing from 30 million in 2014, 13 million in 1999, and 6 million in 1993 (IGF, 2018). Table 1.1 shows an estimate of ASM employments and dependents in selected African countries (IGF, 2018)). ASM contributes 15 to 20% of the global output of minerals and metals (Buxton, 2013; Hilson, Mondlane, Hilson, Arnall, & Laing, 2021), produces up to 20% of all diamonds, 20% of gold, 80% of all sapphires (Buxton, 2013; Eniowo et al., 2022) .Because of these, Mutemeri, Walker, Coulson, & Watson (2016) argued that ASM should be incorporated as part of poverty alleviation strategies rather than being viewed as a problem that must be phased out. It is therefore important that the benefits of ASM are harnessed, and the negative impacts mitigated.

Table 1.1 Estimate of ASM employment showing minerals mined in selected sub-Saharan African countries (IGF, 2018)

Country	Directly working in ASM (in thousands)	Estimated Number of Dependents (in thousands)	Main mineral resource mined by ASM
Angola	150	900	Diamonds
Burkina Faso	200	1,000	Gold
Central African Republic	400	2,400	Gold, diamonds
Chad	100	600	Gold
Côte D'ivoire	100	600	Gold, diamonds
DRC	200	1,200	Diamonds, gold, coltan
Eritrea	400	2,400	Gold
Ethiopia	500	3,000	Gold
Ghana	1,100	4,400	Gold, diamonds, sand
Guinea	300	1,500	Gold, diamonds
Liberia	100	600	Gold, diamonds
Madagascar	500	2,500	Coloured gemstones, gold
Malawi	40	-	Coloured gemstones, gold
Mali	400	2,400	Gold
Mozambique	100	1,200	Coloured gemstones, gold

Niger	450	2,700	Gold
Nigeria	500	2,500	Gold
South Africa	20	-	Gold
Sierra Leone	300	1,800	Gold, diamonds
South Sudan	200	1,200	Gold
Tanzania	1,500	9,000	Gold
Uganda	150	900	Gold
Zimbabwe	500	3,000	Gold, diamonds, coloured gemstones

1.1.2 Legal Codes on ASM

A universally accepted definition of ASM has not been achieved (Hentschel et al., 2003; Zvarivadza, 2018). The definition of ASM adopted in each country would depend on each country's national legislation and national mining policy. In Nigeria, the Nigeria Minerals and Mining Act of 2007, describes the conditions that qualify an organization to be classified as ASM and be considered for a small-scale mining lease (Adefulu, 2010). Article 90 of the Act stipulates that the area covered by a small-scale mining lease shall not exceed 3 square kilometers and shall not be less than 5 acres. Article 49 of the Act further stipulates that a qualified applicant for a small-scale mining lease is:

(a) A citizen of Nigeria with legal capacity and who has not been convicted of a criminal offense; or

(b) A mining co-operative; or

(c) A body corporate duly incorporated under the Companies and Allied Matters Act (CAMA); or

(d) The holder of an exploration license granted in respect of the area subject to the application provided that the applicant has fulfilled all the conditions attached to the exploration license.

The Mining Act in Nigeria does not expressly make provision for registration of an "artisanal mining" operation, but artisanal miners are encouraged to come together and form a "mining co-operative" which makes them eligible to acquire a small-scale mining lease. According

to Adefulu (2010), to promote the formation and development of mining co-operatives of artisanal and small-scale miners, the Nigeria Minerals and Mining Act (article 91), states that the government through its ministry shall provide the following extension services to duly registered and performing mining co-operatives of artisanal and small-scale miners:

(a) Prospecting and exploration services to be provided for registered mining co-operatives to determine the geological setting, structure, and nature of occurrence, quantity, and quality of minerals being mined;
(b) Provide mineral testing standards and the determination of minerals grade;
(c) Provide proven mineral reserve evaluation including feasibility report;
(d) Assist artisanal and small-scale miners in mine design and planning suitable for the deposit;
(e) Teach adequate mining related skills to artisanal and small-scale miners and regularly introduce them to new mining technology.

How well the above-stated extension services have been provided by the government to artisanal and small-scale miners is yet to be fully investigated. Also, the question remains as to how well the support of the government has helped artisanal miners to have well-funded mining operations.

1.1.3 Forms of ASM Practice

When categorizing ASM, attention must be placed on the form and origin of the operation being carried out. It is important to understand the nature of the ASM operation being carried out in a locality as a way of finding possible mediating measures to any challenge that may emanate from such activities. The different types of ASM practice seen in the literature are summarized in Table 1.2.

Table 1.2. Different forms of ASM practice across sub-Saharan Africa

Form of ASM practice	Attribute(s)	Case studies	Reference(s)
Traditional ASM	• Involves miners who have been practicing the operation for ages, and for them, it is cultural and a way of life. • The miners view artisanal mining operations as their cultural heritage and they consider it legal, hence they do not feel the expediency of obtaining licenses issued by the government.	Ashanti kingdom in Ghana	Boadi, Nsor, Antobre, & Acquah (2016)
Cohabiting ASM	• These ASM operators operate near large-scale mining companies. • They are mainly informal, and they encroach into concession areas of large-scale mines (LSM).	Ghana and the Democratic Republic of Congo	Jamasmie (2016)
Seasonal ASM	• It occurs when local community dwellers take up ASM, seasonally, to complement other village occupations such as farming. • Village farmers who practice seasonal ASM often venture into mining relatively high-value minerals, typically gold or precious stones during the off-season of farming.	Nigeria, Zimbabwe, Malawi, and Ghana	Oramah et al. (2015); Gadzama (2015); Hilson (2016)
Shock pull	• It occurs when there is a major economic crisis that influences people to move to ASM for succour.	Mali, and the Democratic Republic of Congo (DRC)	Zvarivadza (2018)
Rush or Influx	• It occurs when there is a sudden rush or influx of people from within or outside a territory to exploit newly discovered minerals.	Madagascar, Tanzania, and Malawi	Hilson (2016)

As seen in Table 1.2, the varying forms and roots of ASM practice across different countries imply that different approaches may have to be applied in each clime for any intervention program on ASM. As such, concerning ASM, there can be no “one size fits all” approach.

1.1.4 Classification of ASM

The classification criteria used for the mining industry vary from country to country. The interphase between ASM on one hand and large-scale mining (LSM) on the other hand, remains unclear in an academic discussion (Rosles, 2019).

To classify ASM, some national policies use the volume of production in tonnage (Columbia), the number of the workforce (Chile, Pakistan, and the United States), or the amount of capital invested (Argentina and Thailand). Some also use the level of

mechanization and the type of mineral titles being used for the operation (Ghana, Zambia, and Zimbabwe)(Adefulu, 2010; Chaparro Avila, 2003; Kambani, 2003).

Some countries have standard ways of categorizing different subsectors in their mining industry. For example, in South Africa, there is the informal sector (*Zamas Zamas*) and there are micro, small-scale, medium-scale, and large-scale mining enterprises. These classes are standardized using different criteria (Table 1.3). In Zambia, the type of mineral to be mined and the size of the mine area would determine the type of mineral title to be used (Table 1.4), while in Nigeria, the type of mining title to be issued is primarily determined by the acreage to be covered by the proposed mine as well as the expected level of mechanisation (Table 1.5).

Table 1.3. Classification Criteria for the mining sector in South Africa (Minerals Council South Africa, 2020)

Definitive criteria	Micro mining enterprises	Small-scale mining enterprises	Medium-scale mining enterprises	Large-scale mining enterprises	Informal mining sector
Criteria 1	Mining right or mining permit holder	Mining right or mining permit holder	Mining right holder	Mining right holder	No mining right or permit
Criteria 2	Revenue in the past tax year <R10 million	Revenue in the past tax year of R10 to R50 million	Revenue in the past tax year of R50 to R500 million	Revenue in the past tax year >R500 million	Revenue not reported
Criteria 3	<150 employees	<250 employees	<500 employees	>500 employees	No documentation of employee number

Table 1.4. Classification Criteria for the mining sector in Zambia (Kambani, 2003)

Type of mining right	Minerals	Area
Prospecting license	All minerals except gemstone	Less than or equal to 10 km^2
Artisanal license	All minerals except gemstone	Not exceeding 5 ha
A Small-Scale Mining license	All minerals except gemstone	Not exceeding 400 ha
Gemstone license	Gemstones	Not exceeding 400 ha

Table 1.5. Classification Criteria for Mining Industry in Nigeria (Nigeria Minerals and Mining Act, 2007)

Definitive criteria	Artisanal and Small-scale Mining (ASM)	Large-Scale Mining (LSM)
Type of operation	Limited to the use of crude tools/Intense use of manpower	Highly mechanised
Area of land covered	Covers between 5 acres – 3 square kilometers	Above 3 square kilometers
Mining right in use	Small-scale mining lease	Mining permit

Nevertheless, for clarity, a simple yardstick that can be used to distinguish ASM from LSM globally is the level or scale of production. For example, a typical large gold mining operation can process up to 10,000 tonnes of ore per day, whereas most ASM operations will hardly process above a few tonnes per day (Hentschel et al., 2003). Although, due to a large number of operators in ASM, the total production on a national scale is always significant, sometimes even exceeding that of LSM. As an illustration, while reporting on monthly gold production, the Governor of the Reserve Bank of Zimbabwe reported that in July 2017, LSM produced a total of 930kg of gold while artisanal miners produced 1.2t of gold (Zvarivadza, 2018).

In some studies, the terms “artisanal mining” and “small-scale mining” are two different levels of operation in the mining industry (see, Kambani, 2003). In some, the terms are used interchangeably (Saldarriaga-Isaza, Villegas-Palacio, & Arango, 2013; Sinding, 2005), while in others, the terms are combined and used as one entity, as in “Artisanal and Small-scale Mining (ASM)” (Eniowo et al., 2022; Saldarriaga-Isaza, Arango, & Villegas-Palacio, 2015) .In this study, “artisanal mining”, “small-scale mining” and “artisanal and small-scale mining” are all used interchangeably which is the common nomenclature used in Nigeria, the case study for the research. Thus, in this study, ASM is regarded as the crude form of mining that is limited in mechanization and investment and characterized by low productivity, poor safety conditions, and a negative impact on the environment.

1.2 Potential and Challenges of ASM

If well harnessed, the potential of ASM is huge. As an illustration, there is immense opportunity for ASM in the gemstone industry in Africa. Africa is a rich source of gemstones yet only accounted for 3.3% of the total global exports of gemstone adorned pieces of jewelry in 2015 (UNComtrade, 2018). This is because the gemstone mining sector is dominated by artisanal miners, who live in poverty. Thus, a large chunk of the gemstone exports is rough, without much value-added after mining (Musiyarira et al., 2019). The global market for rough gemstones was estimated between USD 17 Billion and USD 23 Billion and this demand is expected to rise based on consumer spending which is increasing (Musiyarira et al., 2019). The gemstone market is a portion of the luxury international business (IB) serving $1.2tn global market, which is estimated to have grown by an annual compounded rate of 6 percent from 1996 to 2017 (Roberts, 2019).

Though ASM has immense potential, its associated challenges are quite enormous. The occupation is commonly known for its associated social, health, and environmental hazards. Generally, ASM is associated with child labour, environmental pollution (e.g., mercury and lead contamination), poor health and safety concerns, and several social menaces (Hilson, Hilson, & Maconachie, 2018; Salo et al., 2016). Because of these, in many mineral-rich countries around the world, ASM is considered an economic activity that needs to be discouraged to create space for Large-Scale Mines (LSM) (Cuvelier, 2019).

Many studies on ASM have focused on the negative impacts the practice has on health, safety, and the environment. However, a vital approach to assist the profession and yet still ameliorate its negative impacts would be to upgrade the occupation itself to a more meaningful, sustainable, and productive enterprise. Thus, salvaging the occupation should be considered, rather than discouraging the existence of the profession in its entirety.

Through a review of the literature, four broad dimensions to the challenges militating against the upgrade of ASM activities were identified and are shown in Figure 1.1. The underlined portion in Figure 1.1 is of interest in this study.

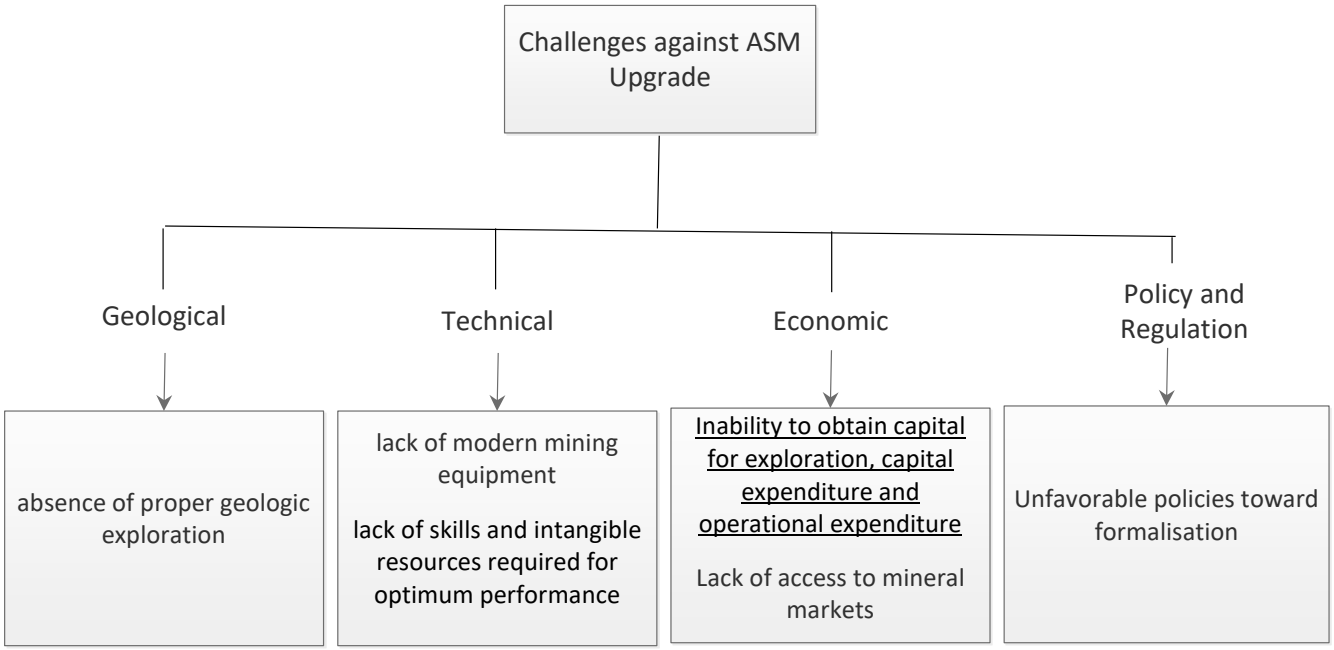

Figure 1.1. Summary of Challenges facing ASM Upgrade (Author's review)

Some studies have examined the requirements for the upgrade of artisanal mining and how to increase its contribution to nations' development. Lack of access to credit facilities has been identified as a primary constraint to upgrading the operation of artisanal mining (Adesugba, 2018; Environmental Law Institute, 2014; Reichel, 2019). The lack of investment at the early stage is a common challenge militating against the development of the sector. As an illustration, a recent survey carried out by the Minerals Council in South Africa identified the problem of early-stage funding in the Junior mining sector (which comprises mining explorers, micro, small and medium-scale miners) of the country. Similarly, studies such as Azobu (2015) and Dorin et al (2014) decried the limited funding

for the ASM sector in Nigeria leading to the use of crude tools for mining, thereby limiting the economic contribution of the industry.

Again, the recent World Bank's *Doing Business* 2019 report on small and medium scale enterprises (SME) identified access to credit as one of the constraints to the ease of doing business for SMEs in low and middle-income economies (The World Bank Group, 2019). The persistence of informality in the ASM sector has been traced to a lack of sustainable finance mechanisms for artisanal miners. Details of available financing opportunities for ASM activities are discussed in Section 1.4. Notably, several African countries have made efforts towards formalising the ASM sector in recent history (Siwale & Siwale, 2017). However, Perks (2016) argued that insufficient financing holds clues as to why informality persists in the ASM industry.

Most ASM operators would like to semi-mechanise to upgrade production capacities or develop new reserves. Studies, such as Mushiri, Jirivengwa, and Mbohwa (2017) attribute the low recovery in ASM to the deficiency of modern equipment for operations such as hoisting. But the reality is, that access to credits and formal banking is difficult for ASM miners, and they face critical problems dealing with formal financing (Hentschel, Hruschka, & Priester, 2002).

There may be a reasonable concern in some quarters that artisanal miners lack the skills required to operate better technology (see, Saldarriaga-Isaza, Villegas-Palacio, & Arango, 2013). This premise is typically explained by the participation of women and children in these mining activities; children who ordinarily should be in school. The perceived consequences of low level of education of the miners are in twofold: the disregard for environmental protection in the operation (Spiegel & Veiga, 2005) and lack of skills to operate safer and efficient technologies (Saldarriaga-Isaza et al., 2013).

However, not all ASM miners lack technical competence to operate better technologies. As an illustration, The empirical study of Perks (2016) on ASM in Tanzania and Rwanda for example, presents a contrary notion to the general perception of poor skillset of artisanal miners. Notably, artisanal miners in this case study were quite knowledgeable in the use of technology; some have worked and were retrenched from large-scale mining companies due to redundancy in the labour market, while some others have seen the use of the heavy machineries in adjacent mine sites, and have learnt its operations overtime. Yet, without financial resources, they were forced to make do with what is readily available for their own operations. Thus, in this instance, the main bottlenecks for ASM operators are the lack of resources to be able to "replicate or adapt mining techniques" (Perks, 2016).

A landmark study by Hentschel et al. (2003) on the associated problems of ASM in the area of finance identified six key challenges and they include: difficulties in low-cost preparation of feasibility studies; uneconomic investment decisions; lack of capital; high tax and royalty burden; limited access to foreign currency; and limited access to investors and equity capital. A more recent study by Planetgold (2020a) identified the following constraints and barriers to financing: perception of the ASM sector as high risk; association of the sector with criminal activities; poor performance of previous ASM financing initiatives, where miners have struggled to pay back loans; and governments and other lenders' lack of understanding of the potential for development of the ASM sector.

The identified financial challenges stated above are highly connected. For example, lenders' lack of understanding of the potential of ASM can be attributed to the difficulties of the miners in preparing low-cost feasibility studies that would indicate the potential of the investment. Again, mineral exploration is capital intensive and the unavailability of exploratory data that provides proof of mineral reserves compounds the challenge for ASM investors. Conventional mining operations are usually preceded by a detailed

Environmental Impact Assessment (EIA) that enables the identification of the impact of the proposed mine development on the existing environmental conditions within the vicinity of the proposed mine. The challenge in this regard for ASM operators is the expensive and onerous nature of a typical EIA (Duthie & Renova, 2017). Thus, ASM operators typically do not carry out EIA prior to mining operation, which implies that they usually do not have legal documents that could ascertain that the mining operations is carried out safely with minimal adverse effect on the environment. In all, ASM operators are therefore confronted with the challenge of proving to investors that their operation is , viable and safe , which is a herculean task for the mostly uneducated miners, leading to the apathy of formal lenders in the industry.

1.3 Existing funding mechanism for ASM operations

A review of empirical findings on available funding for ASM activities indicates that the bulk of the operations are self-financed. They also obtain funding from other sources. The funding sources, their structure, benefits, and drawbacks are further explored below.

1.3.1 External informal financing

One of the most common sources of funding for artisanal mining across sub-Saharan and other developing countries is what can be termed ‘external informal financing’. It typically involves miners receiving funds for investment from external sponsors who have an interest in the mineral to be mined. Mostly, these sponsors are buyers who provide investment capital to miners in exchange for an agreement that the miner sell the mineral to be produced to them after completing the mining operation, usually below the market price.

Varying viewpoints have been expressed in the literature about external informal financing. The perception of the importance of external informal financing in sub-Saharan Africa seems to deviate from the view in some other developing countries. As an illustration,

Verbrugge (2014) provides a positive notion based on his experience exploring informal financing arrangements in Southern Philippines. In these financing arrangements, described in the study as 'back-financing', the financier retains a larger share of the ore proceeds after removing operational expenses and the landowner's share, then leaves the remaining share to the miner. Verbrugge (2014), looking at gold mining, argues that artisanal mining is a dangerous operation and miners may follow the veins of gold deeper into the earth, which increases the risks of flooding or collapse of the excavations. At this point, the ability to continue with the operation usually depends on the availability of cash to provide reinforcement and other equipment. The intervention of external financiers, therefore, becomes very helpful. In this case study, it is further argued that the benefit of such arrangement is that the risks are shared among the participants in the investment, and it enables the miners to continue with their operation, focusing on the mining activities and not worrying about subsistence needs.

However, across sub-Saharan Africa, the findings of empirical studies on informal financing arrangements are rarely positive. For example, Perks (2016) who looked at the informal financing arrangement in Tanzania and Rwanda, asserts that the way such finance and trade relations are structured usually leads to artisanal miners receiving lower market value for their mine produce. In this case study, it is argued that the absence of formal financing opportunities and technological support for their operations have pushed miners to adopt short-term mineral extraction strategies which rely on informal arrangements with outside financiers, traders, and sometimes large-scale mining companies to access the global mineral market. Perks (2016) argue that such a form of capitalisation prevents the miners from having the decision-making power to plan far into the future on their business.

This viewpoint is similar to those of Hilson and Ackah-Baidoo (2011) who studied informal financing arrangements in Ghana. In this case study, the sponsors usually require high-

interest rates from the miners, in addition to the precondition that miners agree to sell their produce to the sponsors on 'inequitable terms'. There are instances where sponsors (who are also buyers) ask for a price cut of up to 10-15% less the market rate. Consequently, the report of Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (2018) asserts that the financiers which the study described as 'power holders' in ASM, make the largest share of profit, while those doing the work on the ground barely make enough to survive. Fold et al (2014) used these lessons to justify why interventions downstream the gold value chain, on access to mineral market, could facilitate the formalisation efforts upstream for artisanal miners.

The body of literature further moots the potential for vested interests of financiers to subvert ASM formalisation by governments and funding agencies such as the World Bank. Perks (2016) again illustrates how middlemen and financiers resisted technical and financial assistance by the World Bank to artisanal miners in Tanzania in 2014. These actors who pre-finance a large majority of gold mines in the country, considered outside assistance as damaging to the monopoly they have on gold supplies from the artisanal mine sites.

While some documented cases expose the opportunistic tendencies of financiers to exploit the informal nature of ASM, there are instances where legitimate license holders who are not able to acquire the funds needed to advance their operations, willingly make way for artisanal miners on their concession areas, just so they could have access to the mineral to be mined. Based on experience in Uganda, Siegel and Veiga (2009) provide a tale of how a small-scale license holder could not afford to employ a formal mining crew, thus, allowing 'illegal' miners to trespass on his concession area, while supporting them with tools and meals, with the agreement to purchase the gold they produce. The study argues that such a scenario underscores the flaw in the effort to formalise ASM since even a license owner

"remains unable to access technical and financial resources to advance his operation beyond the live-and-go-on artisanal stage" (Siegel & Veiga, 2009).

1.3.2 Donor interventions

Another major source of funding for ASM operations is through grants by international and domestic donor agencies. Some of these grant schemes are carried out by the donor agency in collaboration with the host government. A typical example of such donor initiatives is the World Bank support in Nigeria which runs to the tune of US$120 million under the Sustainable Management of Mineral Resources Project (SMMRP), under which US$10 million was earmarked for ASM (Oramah et al., 2015). According to IGF (2018), the SMMRP ran from 2004 to 2012 in Nigeria, provided 245 grants to 147 ASM cooperatives and 98 community entities, and included projects to enhance granite, gravel, sand, and laterite quarrying. A report by the world bank on the SMMRP in Nigeria, rated the performance of the funding scheme as 'satisfactory' (World Bank, 2012).

A similar World Bank SMMRP scheme in Uganda is documented in IGF (2018), which ran from 2003 through 2011. To access this grant, miners only needed to form groups and be further trained on financial management and procurement. IGF (2018) noted that the scheme motivated several ASM associations to start village savings and loans associations that could provide small loans to members in times of need (e.g., to pay children school fees, build houses, etc.). In Tanzania, Pedersen et al. (2019) examined a World Bank intervention program, again through SMMPR, and identified its positive contributions; the intervention supported the current efforts to upgrade the ASM industry in the country which also fits into the current resource nationalism agenda of the country.

It is noteworthy, that donor grant funding is helpful in the short term, but it usually does not align with a business-led approach to develop sustainable long-term solutions. Additionally, as expressed in Siegel and Veiga (2009), donor interventions by international development agencies often come in form of limited-term 'grants' and not 'loans'. It has been suggested that a more sustainable approach would be for development agencies to lend to miners or miners' cooperative societies as a way of addressing the gap of missing capital. This can better enhance the viability of such operations. Another drawback is that gaining access to grants comes with stiff competition. Thus, even when a miner manages to present every requirement, having access is still not assured.

1.3.3 Government loan facilities

Siegel and Veiga (2009) drew evidence from Namibia and Mozambique on the implementation of government loan facilities to ASM. In Namibia, the government provided US$92 million in loans through the *Mineral Development Fund* for projects emphasizing the sinking of shafts, exploration, and mine expansion. The loans were provided using low-interest rates, slow repayment periods, and minimal bureaucratic overhead. The loan scheme has recorded a 92% repayment rate. Also, a similar fund was provided in Mozambique which offered credit facilities, provided miners could provide mining license, feasibility study, plan for repayment, and proof of collateral (20% of the loan amount) (Siegel & Veiga, 2009). The key takeaway from these loan schemes is that they were relatively successful.

Planet gold (2020a) reports a similar loan scheme in Ghana, around the mid-2000s, where the government provided loans to small-scale miners amounting to US$500,000. The loan was provided through the government's *Mineral Development Fund* and coordinated by officials of the *Minerals Commission*, which is the country's major mining policy-making

body. The loan was provided primarily to gold and salt miners. To access the loan, the miners were required to form cooperatives and were collectively bound by the terms of the loan. The loans were provided in form of cash, tied to equipment and consumables, and beneficiaries were required to repay the loan in agreed instalments at a subsidised interest rate. Another feature of the scheme is that miners were required to share the mining machinery purchased such as crushers, pumps, and generators. The result of the findings on the impact of the scheme is mixed. In one town, Konongo, in the south of the country, the program was relatively successful despite the initial teething problems, as borrowers agreed to the terms of the loan and the requirements concerning repayment. Whereas in another district, Talensi-Nabdam, in the north of the country, there were considerable friction between members of a group that received the money, which eventually undermined the intervention (Planetgold, 2020a).

There are recorded attempts in the literature of government loan intervention that was not quite successful. An example is a South African government loan scheme to provide support for small-scale mining projects, managed by the National Steering Committee (NSC) under the supervision of the South Africa Department of Mineral Resources (DMR) (now known as Department of Mineral Resources and Energy, DMRE). The funding structure for the loan was 90% loan, and applicants were required to source for the remaining 10%. The funds were provided for equipment purchase, operational costs, and rehabilitation guarantees. Findings on the performance of the loan scheme indicate that borrowers were unable to repay their loans, and that led to the program's cancellation in 2005. However, it was argued that one possible justification for the scheme's failure is that the bulk of the loan was provided to those in the industrial minerals sector, which has a relatively smaller profit margin. Perhaps interventions in small-scale gold mining, having much higher profit

margins, could have led to different outcomes. Another justification for the failure of the scheme was the inability of the DMR to monitor borrowers or pre-screen their applications.

Apart from direct funding of ASM operations, there are documented cases in the literature where the state got involved in a section of the value-chain of ASM mineral production to enhance formalisation efforts. An example of this scenario was reported in Fold, Jønsson, and Yankson (2014) wherein in 1990, the Tanzanian government (through the Bank of Tanzania) legalised the selling of gold to government-appointed banks. The state's policy aimed to reduce the illegal trade and smuggling of gold in the country. With this policy, no questions were asked about the origin of the gold. Thus, the system became popular among ASM operators who suddenly got access to legal and locally available gold purchasers (Fold et al., 2014). Consequently, the official gold export rose rapidly from just above a million US dollars in 1989 to above 40 million US dollars in 1992, reflecting a significant reduction in illegal gold export.

The observed limitation of government loans in the ASM industry is in its sustainability. Even when government loan schemes are successful, they are often short-lived. Also, the criteria set out for access to government loans are sometimes out of reach for most artisanal miners.

1.3.4 Miners' Cooperatives/Village Savings and Loans Associations

Mining cooperatives (sometimes called associative entrepreneurship) are local associations set up by local miners for savings and easy access to credit as a service for their members(Saldarriaga-Isaza et al., 2015). The creation of mining cooperatives presents an alliance between individual interests to achieve collective benefits for all those involved in

the activity. As such, Alves, Ferreira, and Araújo (2019) argued that the alliance into cooperatives can be a key element to improve sustainability in the mining sector. They continue by arguing that, as a business model the use of cooperatives has not been fully explored in the mining sector when compared with other sectors such as agriculture, health, credit, and consumption, where they have recorded success. Some successful cases of cooperatives, however, have been documented., Perks (2016) reports a successful cooperative model adopted in Rwanda where cooperatives are obliged to employ an administrator/accountant whose role is to formalise the cooperative's dealings and produce better accountability of their financial resources. Calling it associative entrepreneurship, the collaboration between mining cooperatives and government regulating agencies has produced some successes in Rwanda; the cooperatives now pay social insurance and pension to their members in addition to access to loans for members.

With the assistance of the state regulating agency, cooperatives have managed to hire the services of geologists to evaluate potential reserves (ibid). This underscores the potential of self-regulation in the ASM sector (Eniowo & Meyer, 2020). Saldarriaga-Isaza, Arango, and Villegas-Palacio (2015) therefore recommend governments need to strengthen associative entrepreneurship as a way of formalising the ASM industry.

Another initiative that is increasingly in use recently in some sub-Saharan African countries is the village savings and loans associations (VSLAs). Reichel (2019) reports results from community-led savings and credit project implemented by a Canadian non-governmental organisation *IMPACT* in artisanal gold mining communities in the Democratic Republic of Congo (DRC). The scheme recorded very encouraging repayment rates (98%). More importantly, it is believed that such saving groups can contribute to local formalisation efforts since they can significantly increase the financial literacy of their members, which is one of the requirements for formalisation. Still, it must be noted, that VSLAs are potentially not able

to address all financial problems in ASM e.g., major capital investment. However, they can contribute to cover the basic financial needs of miners (e.g. medical bills, children's school fees, food security, housing needs, etc.) before banks or other formal lenders step in (ibid).

1.3.5 Commercial bank loans

Despite the potential of ASM, the absence of formal bank investment in the sector is worrisome. The few recorded attempts to fund ASM operations with commercial bank loans usually have challenges. A typical illustration of an effort to fund ASM operation with commercial bank loans was an initiative to supply credit to emerald miners in Zambia, documented in Siwale and Siwale (2017). To access the fund which was provided by the European Investment Bank (EIB), miners were required to provide bankable documents with requisite technical documents if their applications were to be considered. Siwale and Siwale (2017) continues to assert that “due to the low educational levels among these miners, none were able to submit an application deemed acceptable to the EIB” . More appalling was that in this case, the technical assistance unit of the bank that was meant to assist loan applicants to design bankable documents required miners to pay 30% of the cost required to help design the documents. Where applications for the loan were successful, miners were asked to pay the balance of 70%. In effect, artisanal miners could not afford these costs, and the project completely failed to fund any ASM operation.

1.3.6 Microfinance loans

To fill the funding gap for artisanal miners, another reasonable option would be the creation of microfinance institutions specifically for artisanal mining operations, such as the agricultural microfinance banks and other trade microcredit agencies in developing countries. Blore (2015) noted remarkably, that only a few attempts have been made to

create alternative financing networks specifically for artisanal mining, despite the rise of the microcredit movement. More recent works of literature however provide evidence of microcredit initiatives in the sub-Saharan Africa mining industry that brings glimpses of hope for formal lending in the industry (Planetgold, 2020a). A typical example is the microfinance initiative used to support an equipment lending model based on a 'group sharing' arrangement, in the Bolgatanga and Tongo communities in Ghana. In this model, participants in a group rank their fellow group members according to their financial strength. This rank is used to determine who receives the loan first and to elect a chairperson who coordinates the repayment. One useful feature of this financing arrangement is that the risk was shared across the group members (Planetgold, 2020a).

While microfinance funding may be quite helpful as a funding option for ASM activities, the funding provided by such schemes is usually not enough to cater to efficiently mechanised small-scale mining operations. Thus, there is a need for ASM operations to be able to access commercial bank loans to acquire efficient mining equipment that can scale up their operation, improve their performance, and more importantly, ensure that their operation is safer and more environmental-friendlier. Owing to the perceived risky nature of ASM operations, perhaps banks may lend to miners' cooperatives instead of individual miners, in a way that members of the cooperatives will coordinate repayment within themselves. The role of social ties in bank financing has been hailed by scholars (see, Postelnicu, Hermes, & Szafarz, 2014; Eniowo & Meyer, 2020) who said group lending with joint liability is an important instrument mostly in informal economic activities, because it incentivizes group members to use their social ties to screen, monitor and enforce loan repayment on their peers. Thus, such social ties enhance the collective action of the group members and allows them to coordinate their repayment decisions and cooperate for their own mutual benefit.

In summary, a snapshot of the major credit schemes used to fund ASM operations in selected sub-Saharan African countries and their successes and failures is shown in Table 1.6.

Table 1.6 Credit schemes used to fund ASM in selected sub-Saharan African countries (Eniowo et al., 2022)

Authors	Credit scheme	Country	Remark
Planet gold (2020a)	Government loan facilities	South Africa	Unsuccessful, borrowers were unable to repay
Siegel and Veiga (2009)	Government loan facilities	Namibia	Successful: 92% repayment rate recorded
Siegel and Veiga (2009)	Government loan facilities	Mozambique	Successful, but out of reach to most miners
Spiegel (2012)	Government loan facilities	Zimbabwe	Successful, but short-lived due to the country's hyperinflation crisis
Planet gold (2020a)	Government loan facilities	Ghana	Successful, though had initial teething problems
Perks (2016)	Mining cooperatives	Rwanda	Successful
Reichel (2019)	Village Savings and Loans Associations (VSLAs)	Democratic Republic of Congo (DRC)	Successful
World Bank (2012)	Donor grants - World Bank	Nigeria	Satisfactory
Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development (2018)	Donor grants – World Bank	Uganda	Successful
Fold, Jønsson, and Yankson (2014)	Donor grants – World Bank	Tanzania	The scheme is just emerging.
Fold et al. (2014)	Informal finance	Ghana and Tanzania	Unfavourable to miners
Perks (2016)	Informal finance	Rwanda	Unfavourable to miners
Siwale and Siwale, (2017)	Commercial loan	Zambia	Unsuccessful
Planet gold (2020a)	Microfinance loan	Ghana	Mixed result

1.4 Implication of ASM credit constraint

Although the idea may seem ambitious and visionary, Hinton, Veiga, and Veiga (2003) advocates the adoption of the concept of sustainable development in ASM, which involves a conscious effort towards the realization of a net benefit (economically, environmentally and socially) in the mining operations, right from development phase to the closure of the mine site. It is evident that the tools to achieve this is not available in this sector. Artisanal miners typically lack the skills to conduct safe, healthy and environmentally friendly operations. Even when government set up training centers to equip the technical competence of miners, often, as is the case in Tanzania, these centers offers courses at a rate that is too expensive for an average ASM worker (Kinyondo & Huggins, 2020).

Thus, the key factor responsible for the associated problems of ASM is lack of finance and the inability of its operators to obtain capital for investment to advance their operations (see figure 1.2). This leads to the use of inadequate techniques for mining and processing which results in low recovery and productivity and traps them into crude and inefficient mining and processing. A consequence of this is the poor health, safety, and environmental damage attributed to the occupation. Thus, Richard Noetstaller, in his keynote address at a World bank round table on ASM asserts that “most of the harmful effects of artisanal mining is directly related to the technical and financial limitations typical for the subsector” (Eniowo et al., 2022; Sinding, 2005). The technical limitation here as identified by Sinding (2005) is all about the lack of skills, technical competence and technology that could advance the operations. The problem of skill shortage is further discussed in section 1.2.

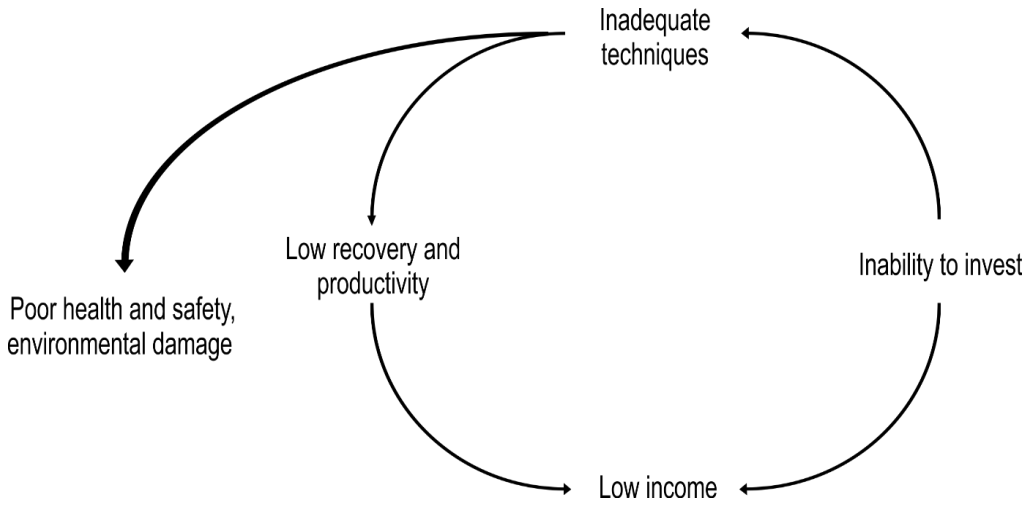

Figure 1.2. Negative circle affecting artisanal miners (Sinding, 2005)

A typical illustration of the offshoot of the ASM poverty circle is in tin ore (cassiterite) artisanal mining in Jos, Nigeria carried out by groups of community peasants using a local sub-subsurface method of mining called *loto*[1]. Mallo (2011) examined *loto* mining and argued that miners using this technology live a hard, insecure, unhealthy, and dangerous life while their earnings remained low – each miner receiving an average income of less than US$1 a day - falling squarely into the broad category of “absolute poverty”. Apart from that, the *loto* mining technique resulted in large-scale environmental degradation which adversely affects the land, waters, and other aspects of the ecosystem.

1.5 Optimising the Contribution of ASM

While most previous studies on ASM have focused on the negative socioeconomic impacts and the enormous environmental hazards traced to the occupation, recent studies have rather focused on measures through which the performance of operators in the industry can be optimised and ways through which their contribution to economic development can be

[1] *Loto* mining involve group of community peasants numbering 10 to 15 who form clusters by separating themselves into groups of those who extract the cassiterite and those who process it. The cycle of operation involve manual digging of pits to an average depth of 30m and hauling water over the ore, sun-drying it and marketing the mineral.

enhanced. Quite a few studies have positioned “formalisation” as the bedrock of the intervention mechanism in optimising the positive impacts of ASM (De Soto, 2000; Hinton, Veiga, & Veiga, 2003; Kinyondo and Huggins, 2020; Salo et al., 2016; etc.).

1.5.1 Formalisation and access to credit in ASM

Formalisation is the means of absorbing existing customary practices—developed informally by miners—into the mainstream of a country’s legal and economic affairs (Siegel & Veiga, 2009). The formalisation of artisanal mining involves the resolution and enforcement of property rights, land-use planning, fiscal regulation, and, more broadly, the implementation of environmental and social norms. It provides an avenue for the government to effectively manage the social and environmental impacts of mining (Salo et al., 2016). Formalisation can be summarised as an effort to upgrade “artisanal mining” to a “responsible small-scale enterprise”. The concept of formalisation for the development of informal occupations such as artisanal mining was prescribed by Hernando De Soto (De Soto, 2000) who argued that by not extending the mine to the informal economy, governments are denying economic freedom to what is in fact the overwhelming majority of the world’s people – it is argued that as much as 80% of the world belongs to the informal/extralegal economy (Siegel & Veiga, 2009).. Now, there is a consensus among scholars, governments and global development organizations that the foundation of intervention on ASM lies in formalisation (Kinyondo & Huggins, 2020)..

Formalisation starts with legalisation of mining operations, but it encompasses more than just legal issues. It involves several issues which include: legal (acquisition of mining permit, conducting environmental impact study); technical (access to geological data, use of modern and efficient equipment for mining and processing); institutional support (capacity building for cooperatives and associations, which could bring about easy monitoring and

coordination); and financial (capitalization of the operations, collection of taxes and royalties) (Kinyondo & Huggins, 2020).

A path towards formalisation of the ASM sector must be pursued as a way of enhancing the enormous potential of the sector and tackling its challenges. Informality breeds chaos. The clashes usually caused by the intrusion of established large-scale mines by illegal miners make a case for the formalisation of informal ASM (I/ASM). Examples of Illegal miners are *Galamsey* miners in Ghana and the *Zamas Zamas* in South Africa. These illegal miners usually intrude into large-scale mining lease areas illegally, sometimes these intrusions are carried out violently. For example, in Ghana, a gold mine owned by AngloGold Ashanti was overrun by thousands of illegal miners in 2016, and the mine was forced to evacuate employees (Jamasmie, 2016). This unsafe investment environment creates doubt in the mind of investors in several potential mining destinations in Africa.

Furthermore, as these illegal miners operate without consideration for safety, there is usually a record of high casualties in their operations. For example, at the copper mine operated by Glencore in Congo, 43 bodies have been initially recovered from the mine when a landslide killed some illegal miners who occupied the mine site. According to Bloomberg (2019), over 30 illegal miners died in an explosion that occurred in the shaft of an unused gold mine in South Africa in the year 2017.

ASM, whether formal or informal, cannot simply be wiped out using heavy-handed techniques, otherwise, a more dangerous social menace could be created. Rather, the operations must be formalised, and upgraded to meet global best mining practices. By capturing informal miners to the formal sector, and designating mine spaces for them, it is perceived that the clashes between the formal and informal mining sectors would be abated. In line with this, recent studies on ASM concentrate on how to formalise, strengthen, and

upgrade ASM companies. Some of the strategies which have been put forward by researchers include the creation of ASM designated areas (formalisation of ASM “spaces”) (Corbett, O’Faircheallaigh, & Regan, 2017); provision of revolving loans for ASM companies (Spiegel & Veiga, 2005); establishing Village Savings and Loans Associations (VSLA) (Reichel, 2019); creation of mineral gem buying centers (Adesugba, 2018); training of ASM operators on economic sustainability (Veiga & Marshall, 2019) among others.

For sustainable formalisation of ASM operations to be achieved, the financial inclusion of ASM operators is important. However, the relationship between formalisation and financial inclusion is a complex one (Reichel, 2019). While Hilson and Ackah-Baidoo (2011) suggest that formalisation is a prerequisite for access to finance for ASM operators, the absence of formal financial services is a major obstacle to the development and formalization of ASM, especially in areas affected by conflict (Reichel, 2019). In places where there are available formal financial institutions, there is often that challenge of ease of access of funds for ASM operators. The reasons for this would be discussed in subsequent paragraphs. This has opened wide doors for informal sources of securing investment in the ASM sector which was discussed in section 1.4.1.

Recent UN guidelines on ASM formalisation describe access to finance as “one of the most pressing needs” of artisanal gold miners (Reichel, 2019). Curiously, few attempts have been made to create alternative financing networks specifically for artisanal miners, even with the rise of the microcredit movement (Blore, 2015). A force field that presents the forces for, and against the upgrade of ASM is shown in figure 1.3.

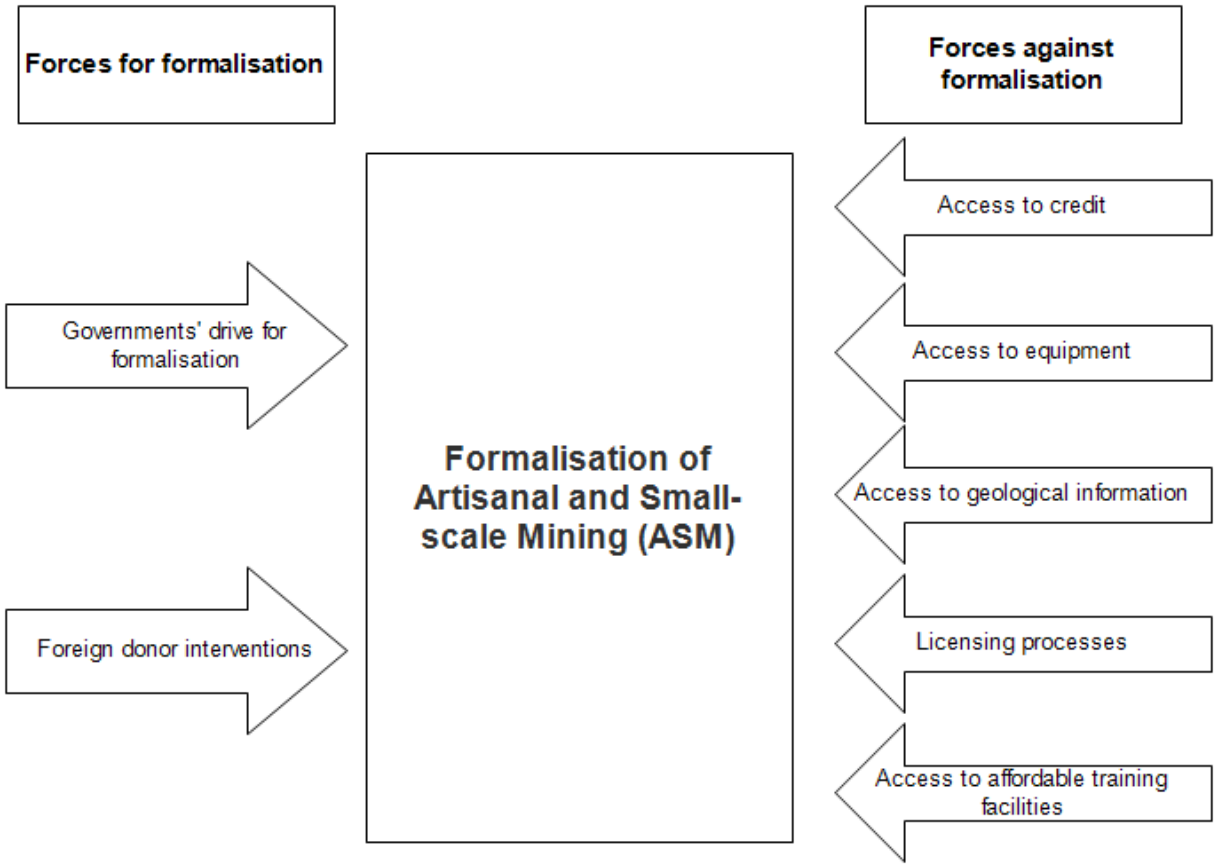

Figure 1.3. Force Fields on Artisanal Mining Upgrade (Author's construction)

By focusing on the lack of access to finance for ASM operators, it can be observed that the associated financial risks involved in the operation are a primary cause. Studies have shown that it is harder for small businesses to obtain credit than for larger firms because they (small businesses) can experience a debt gap caused by insufficient business collateral or cash flow related problems (Benning, 2000). For ASM, the reasons for poor financial service can be attributed to a long list of credit risks: the remoteness of mining areas which makes service delivery not profitable, the itinerant nature of miners, the lack of land tenure which doesn't provide for physical collateral, the often informal or illegal status of miners, poor financial and business planning skills, little access to geological assessment skills and equipment which would allow identifying the scale and value of the resource and an anticipated guarantee of return on investment, as well as a lack of social collateral (Hayes

and Van Wauwe, 2009). Any combination of these factors can contribute to actual or perceived challenges in making a repayment.

Many of the studies that articulate techniques for strengthening the current formalization efforts emphasizes that ASM generally has very high technical and financial risks. Recent studies that have attempted to develop methods of mitigating the financial risks involved in ASM are discussed in the following section.

1.5.2 Predicting Viability of an ASM Operation

The inability of formal lenders to predict the viability of ASM, by quantifying and pricing the credit risks of such investment, limits the ability of artisanal miners to access formal bank financing. Hilson and McQuilken (2014) highlighted the concern of government-sponsored "mining banks" in supporting ASM operations in developing countries. It is believed that ASM has high technical and financial risks; funding the operations is hence difficult and expensive. It is a fundamental principle that recipients of loans must be creditworthy companies with technically and financially viable operations and projects (Seccatore, Marin, De Tomi, & Veiga, 2014). For ASM operations to be technically viable, modern types of machinery are required. As such, financial/economic viability is a prerequisite for the technical viability of ASM companies.

A nuanced study into the inability of ASM firms to obtain capital for their operation by Seccatore et al. (2014) reveals that the high-risk nature of the investment, occasioned by the lack of guarantee of return or fiscal success is a cause. As a result, there is little attraction for investors in the occupation. This situation is further compounded by the absence of proper geological exploration. Consequently, ASM operators restrict their operational planning to instinct and reliance on experience based on previous operations (Marin et al., 2016).

It is common knowledge that ASM companies operate in poor and unsafe conditions that pose danger to their health and the environment. However, there is a paucity of studies that address the inability of ASM to attract investment and its effect on their poor and dangerous mining practices. Rather most studies have focused on the safety concerns and the effect of the release of harmful substances by these miners on the environment (for example Clement & Olaniyan, 2016; Environmental Law Institute, 2014; Mallo, 2011)

Several studies on ASM explored the need for formalisation of the sector (Hentschel et al., 2003; Hilson & McQuilken, 2014; Siwale & Siwale, 2017, etc.). Similarly, some studies extended the concept of formalisation by focusing on building capabilities of ASM concerning health and environmental sustainability (Boadi, Nsor, Antobre, & Acquah, 2016; Spiegel & Veiga, 2005). Some studies also identified the need for creating designated areas specifically for ASM (Corbett et al., 2017). This study will add to the existing bulk of knowledge on ASM. The study will take it a step further, by focusing on building the creditworthiness of ASM operations.

Recent studies have made advancements on a methodology for creating certainty that can help boost confidence in investing in artisanal mining operations. For example, in a recent approach, there is no need for a large investment to ascertain the feasibility of responsible artisanal mining, like the one required for large-scale mineral exploration. Instead, only proof of 'minimum reserve and replication' is needed for the project start-up (Marin et al., 2016; Seccatore et al., 2014). The 'minimum reserve and replication' is any estimated reserve that can pay back the capital expenditure (CAPEX), an organisational expenditure of the mining business, providing cost for future geological operation and desired profit (Marin et al., 2016). When applied to a real case, it was shown that the reserves required to prove the feasibility of a responsible small-scale operation are of the order of 1/1000 of that required

for large-scale mining (Seccatore et al., 2014). This method simplifies the determination of the feasibility of a new artisanal and small-scale mine.

This concept of 'minimum reserve' could boost mine operators' confidence in venturing into small-scale mining. However, it must be noted that having proof of economic feasibility through proven reserve alone is not a guarantee of the fiscal success of an ASM operation. It is equally essential that ASM companies can service loans obtained for investment. A reasonable way to measure this is to develop a model for credit-risk assessment of small-scale mining investment. This will help ASM stakeholders to evaluate their ability to secure investment. It will help to identify grey areas in their operation limiting them from obtaining funds for investment. It will also help to boost investors' confidence in ASM operations.

The direction of this study is, therefore, a complete focus on the economic aspect of mining. The identified gap in the literature that has generated the problem addressed in this study will be discussed in the next section.

1.6 Problem Statement and Purpose of the Study

The current theory that validates the feasibility of ASM allows us to predict the viability of ASM by estimating the "minimum reserve and replication". However, it does not capture the risk of credit and how it will affect the viability of the ASM investment. The risk of ASM investment cannot be effectively predicted by the sufficiency of reserve alone. To enhance investments in ASM, detailed knowledge of the economic risks involved in the investment is important for both debtholders and investors. As such, there is a need to create a financial risk model that captures the economic (credit-risk) considerations. Thus, the purpose of this study is to enhance the predictability of the viability of ASM by developing a model for estimating the credit worthiness of the operation. The problem discussed, therefore, generates the research questions outlined in the next section.

1.7 Research Questions

It has been shown that recipients of loans should be credit-worthy companies with financially viable operations. ASM, as is being practiced, has been unable to attract formal lending partly because there is no standard for formal lenders to measure the viability or credit worthiness of such investment. It is, therefore, necessary to create simplified tools and methods to estimate the viability of ASM operations that is void of the encumbrance seen in banks' due diligence for large mining companies. This leads to the following primary research question:

How can the creditworthiness of an existing ASM operation be evaluated, relative to the credit risk variables inherent in a typical ASM operation?

The primary research question is divided into the following secondary questions:

a. *What methods do financial institutions adopt in assessing the credit risks of ASM operations in the study area?*
b. *What is the level of the practical use of a minimum reserve to evaluate the risk of ASM investment in the study area?*
c. *What model can be developed, using the knowledge of ore reserve, to predict access of an ASM operation to a formal fund?*
d. *What model can be developed to predict the credit worthiness of an ASM operation using the credit risk variables?*

1.8 Research Design

This research is a mixed method of research, that is, it combines both qualitative and quantitative forms of research. Qualitative research develops an in-depth exploration of a central phenomenon such as artisanal and small-scale mining credit risks as indicated by

Creswell (2012). This research is qualitative because it relies on unstructured data such as field notes to be written by the researcher during his field observation and the use of semi-structured interviews. It would also involve audio recordings by the researcher during field work on the study. The research is likewise quantitative since it involves the use of a well-structured questionnaire to elicit information on the creditworthiness of ASM firms from the research participants. One major benefit of adopting a mixed method of research is that data collected from one source could elaborate, enhance or complement data from the other source (Creswell, 2012).

1.8.1 Model on the creditworthiness of an ASM operation

This study designs model for the creditworthiness evaluation of a responsible small-scale mining firm. Traditionally, credit risk models are developed using historical datasets from banks and lenders on loan performance. However, preliminary investigations indicate that artisanal miners typically do not enjoy formal lending as larger companies. This is primarily due to lenders' inability to assess their credit worthiness, which this study seeks to address. Thus, since historical dataset on ASM creditworthiness is non-existent, in place of using a dataset of loan performance to obtain default occurrence, this study uses non-financial data obtained through survey from artisanal miners, coupled with the conditions given by formal lenders for loan access, to develop models on the likelihood of access to formal loan. To achieve this, a binary logistic regression model is developed following the study of Behr and Guttler (2007). In this logistic regression, the dependent variable is a dummy variable that takes value 1 if an ASM operator receives a formal loan and 0 otherwise. The independent variables are the potentially relevant parameters that may drive credit risk. For this study, the independent variables include the formality or legal status of the operation; the duration of the existing operation, evaluation of itinerant nature of miners, knowledge of reserve estimate of the mineral deposit, ability to afford loan interest rate, availability of loan

guarantors (which stands as a form of collateral security), availability of feasibility report, and plan for reclamation (for environmental protection).

The form of the basic logit model is as shown:

$$\boldsymbol{ln\left(\frac{P}{1-P}\right) = a + BX + e} \quad (1.0.1)$$

where P is the probability that ASM company will receive a formal loan; a is the coefficient of the constant term; B is a vector of coefficients of the independent variables; X is a vector of independent variables, and e is the error term that is log-normally distributed by assumption. The coefficient of the constant and the vector B are estimated through maximum likelihood estimation. The transformation of the dependent variable constrains P to be in the interval [0,1]. This standardization is one of the main advantages of logit regression models and allows for the computation of P by a borrower by simply plugging the borrower-specific variable values into the estimated logit function.

1.9 Methodology

The methodology for this research will consist of three parts: literature review; data gathering from field work; and data analysis and model formulation.

1.9.1 Literature review

A review of the studies undertaken concerning the analysis of the credit risks of ASM operations and mining operations, in general, was undertaken. To better understand the analysis of credit risks, studies that discuss subject areas such as mineral exploration, mine valuation, and measurement of credit worthiness were also reviewed. Each of the areas discussed in section 1.7 was subjected to the following procedure:

(i) Assemble information: Various search tools and library facilities were used to gather information on each of the subjects in question.

(ii) Review information: The assembled information was reviewed, analysed, and collated because of its applicability to the current study.

(iii) Presentation: The results of the literature review are presented in Chapter 2 of this Thesis report.

1.9.2 Data gathering from fieldwork

Data to be acquired from field work include:

- Data from Bank of Industry (BOI) and other formal lenders on method for assessing credit worthiness of artisanal and small-scale miners loan applications
- Data from ASM cooperative societies, unions, and associations, on their knowledge and skillset in some key areas that may affect their credit worthiness.
- The perception of ASM cooperatives, unions and associations on access of artisanal and small-scale miners within the study area to formal lending.

1.9.3 Data analysis and model formulation

Data gathered from field work would be analysed using data processing techniques. Models on the credit risk of ASM investment would be generated based on the results of the data analysis.

1.10 Structure of the Thesis

Chapter 1 introduces Artisanal and Small-Scale Mining (ASM). It discusses the potential and challenges of ASM in developing nations. It further discusses the need for formalisation

and upgrade of ASM to a responsible small-scale mine. It then itemises the existing funding available for ASM activities, stating the structure, advantages, and drawbacks of each funding type. The need for predictability of economic viability and credit risk of small-scale mines was also discussed. Once these concepts have been defined, the statement of the problem of the study and the research questions were outlined. Lastly, the methodology adopted for the study was presented.

Chapter 2 of this thesis covers a literature review on the estimation of economic viability and Credit-risk. The chapter discusses some methods and tools (for mineral inventory estimation) used in estimating the viability of a mine. The chapter further explains the concepts of risks in mining investment, with a special focus on small-scale mining operations.

In Chapter 3, the source of data used in this study is explained. Also, the methods used in generating the models for evaluating the creditworthiness of a small-scale mining operation are explained. In Chapter 4, the result of the evaluation of the developed model is presented and the interpretation of the result is carried out.

The conclusion based on the findings of the research is presented in Chapter 5. In chapter 6, a recommendation based on the findings from the study is done followed by suggestions for further study.

CHAPTER 2 LITERATURE REVIEW

Chapter 1 of this thesis described the need for the study. The problems of the study were outlined, and the key areas of investigation were discussed which is to optimise the viability of artisanal and small-scale mining (ASM) investment by developing a model for estimating the occupation's creditworthiness. To ensure that the objectives identified in chapter 1 are achieved, Chapter 2 of this thesis covers a literature review of estimation of economic viability and Credit-risk in mining operations with a focus on credit worthiness prediction for ASM operations.

Firstly, this chapter briefly itemised the stages involved in the life of a mine. Then it discusses the mineral exploration program in detail. Then the chapter discusses some methods and tools used in estimating the viability of a mine and the concept of financial risks analysis in mine evaluation. Additionally, the chapter reviews bankers' methodology for evaluating viability with an emphasis on mining risks.

2.1 The Stages in Mining

Before delving into the detailed discussion on the techniques for estimating the credit risks of a mine, first, it is important to itemise the stages involved in setting up a mine for production and what it entails. The five stages involved in the life of a mine are prospecting, exploration, development, exploitation, and closure.

a. *Prospecting*: This is the search for the occurrence of mineral resources. In some literature, prospecting is classified as part of the exploration phase. It typically involves searching for anomalies that show the existence of traces of a mineral resource in an environment. It is at the prospecting stage that suggestion is made for the exploration of the resource.

b. *Exploration*: this simply means quantification of the mineral resource to determine if the extraction of the mineral should proceed. It involves digging deep holes into the ore body and taking samples that would be used to determine the tonnage and quality of the mineral resource. These details will help to produce a geological model which describes the economic value of the mineral resource deposit. Also, at the exploration phase, “feasibility studies” are carried out to evaluate whether the project is viable or not (see section 2.3.2 for more on feasibility studies). Typically, the bulk of investment decisions is made at the exploration stage. Upon discovering that the mineral resource is ideal for mining operation, an Environmental Impact Assessment (EIA) would be conducted to ensure that the mining operation will not result in environmental degradation. The EIA report will ease the work of authorities in evaluating the impact of the mining operation and will ultimately pave the way for the issuance of mining license.

c. *Development*: The development stage is the opening of the mine for full production. It involves permitting, planning, design, and construction. At this stage, funds are acquired for the project, access roads to the ore body are created. Also, processing plants, office buildings, explosives magazines, waste disposal mechanism and other infrastructures are constructed in preparation for mining.

d. *Exploitation*: This is the actual mining operation. It involves drilling of holes, loading of explosives into drilled holes, blasting, loading, and haulage of produced materials for processing or sales.

e. *Closure*: This is the last phase in the life of a mine. It involves rehabilitation of the mined area after mining operations must have been completed.

f.

2.2 Estimating Viability of a Mining Project

The primary aim of every investment is to make a profit - mining is no different. The purpose of estimating the viability of a mine is to determine if the mineral resource can be mined safely at a profit. Mining investment usually requires a huge amount of funds, it is therefore imperative that those seeking investment in mining have a detail of the value of that prospective mining operation and how much income it can potentially bring.

For a mining project to be able to secure investment from a bank, the project must be deemed viable by the lender's financial model. Typically, the processes involved in the acquisition of a loan from a formal lender for a viable mining project are shown in figure 2.1.

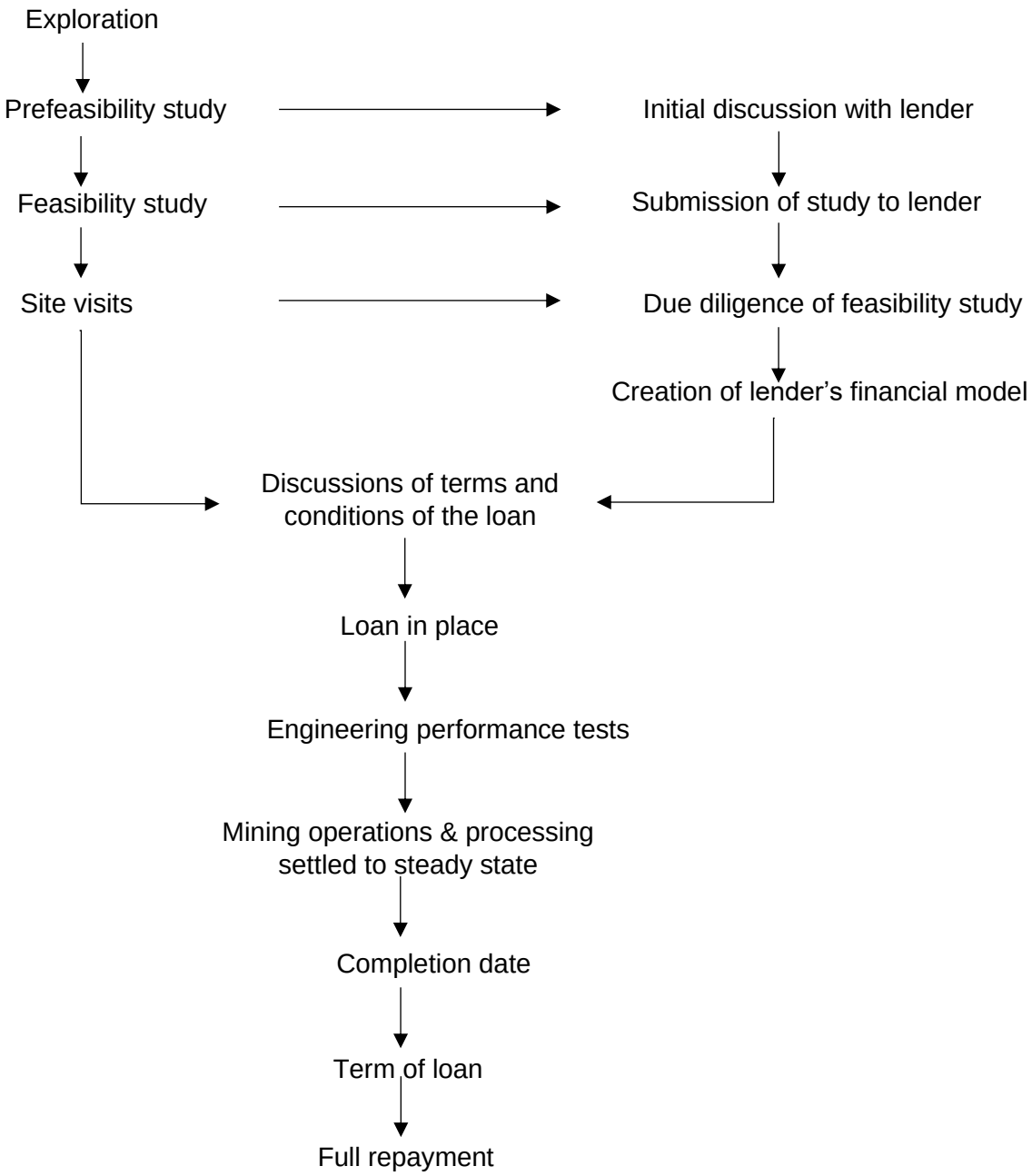

Figure 2.1. The critical path to loan progression2.2.1

Mineral Exploration

The work of establishing the viability of a mine starts with mineral exploration. The life of a mine does not begin the day production commences, but many years before, when the company set out to explore for a mineral deposit (Alastair & Garston, 2004). The exploration is the most critical phase in the life of a mine (the stages involved in the life of a mine were

briefly discussed in section 2.2). The exploration program helps to understand the geology around a mineral deposit. Exploration involves data gathering and quantification of the mineral resource to determine the extent of the resource.

Mineral exploration is usually divided into interlinked and sequential stages, the terminologies used to describe each stage vary in the literature. As the work of exploration progresses, the expenditure increases and the risks reduce as shown in figure 2.2.

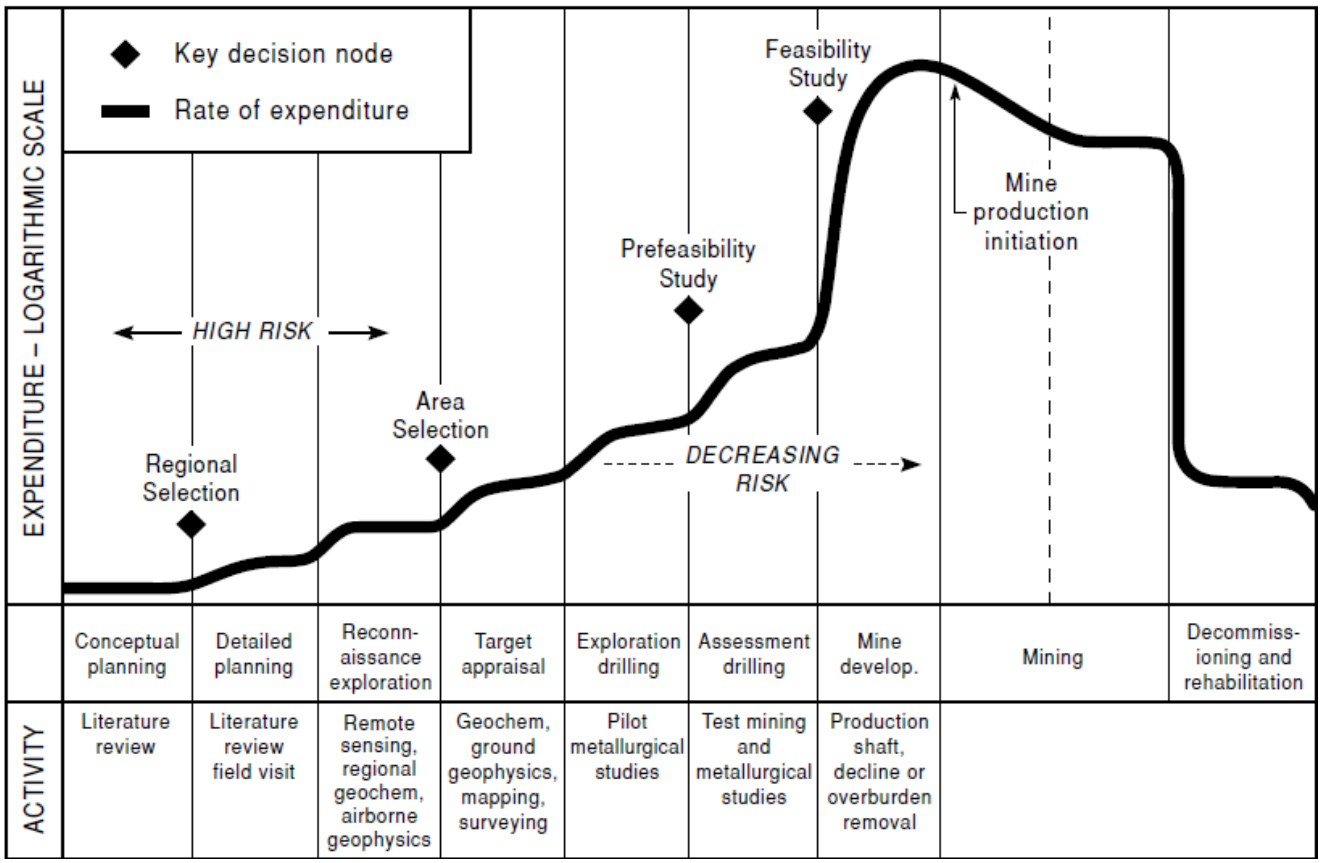

Figure 2.2. Stages of an exploration project indicating level of risk (Moon, Whateley, & Evans, 1995)

The basic required knowledge that a mine planner/investor should have when evaluating a potential mine development is an estimate of how much ore is in the ground, how it can be mined and the costs of extracting it. Runge (1998) opines that in grassroots exploration to

establish the existence of mineral deposits, an initial starting point for evaluation should be that of an assumed ore body. Before any major spending on exploration, a major question that can be asked is: What is the best deposit that can be expected? This hypothetical deposit can be described in terms of grades, shape, dimension, tonnage, depth, and physical location. In such a case, if the evaluation of the best hypothetical deposit does not indicate viability, then clearly, a lesser deposit will not either. For example, an initial evaluation of a hypothetical gold deposit may reveal that ore of 3grams/ton at 100m depth has about the same economic value as an ore of 5 grams/ton at 200m depth. This knowledge can prove valuable for planning since with this early evaluation, the project could have been proven to be nonviable before any huge expenditure on exploration (Runge, 1998).

Once there is justification for investment in an exploration through the evaluation of a deposit, then exploration can proceed. If the hypothetical orebody is proved to be nonviable, exploration may still proceed but there would be some alternative justification for such exploration (Runge, 1998). For a known orebody, further exploration serves the purposes of finding more reserves and understanding existing reserves to ensure greater reliability.

The processes involved in exploration are usually intense, enormous, and sometimes take several years. They are briefly discussed below:

(a) Reconnaissance: The activity of mineral exploration usually begins with reconnaissance (Gandhi & Sarkar, 2016; Haldar, 2018). Reconnaissance is a grassroots exploration that identifies the existence of mineral potential or initial targets. The objective is to study the entire area under leasehold to identify probable mineralised areas (targets) that are worthy of further investigation (Haldar, 2018).

Activities done in preparation for reconnaissance include literature survey, acquisition of geophysical data, synthesis of available data and concepts (if any),and obtaining permission (reconnaissance license/permit) from the government. At the initial reconnaissance stage, the work involves a visit by a geologist or groups of geologists with limited support, to look for outcrops in areas of interest. At this stage, the geologists traverse rock outcrops, soils, or streams and collect samples for chemical analysis (Gandhi & Sarkar, 2016).

Some other activities incorporated in reconnaissance include remote sensing, airborne and ground geophysical survey, regional geological overview, map checking (mapping on 1:250,000 and 1:50,000 scales), pitting, and trenching to expose mineralised zones at ideal locations. Moon et al. (1995) summarised that reconnaissance aims to rapidly evaluate areas highlighted in the desk study to identify targets for follow-up work and drilling.

(b) Prospecting: According to Gandhi and Sarkar (2016), 'prospecting is the first link in a chain of events which hopefully leads to a mineable deposit' . prospecting is the systematic process of searching for promising targets that were identified during reconnaissance (Haldar, 2018). Upon establishing a target after reconnaissance, the land is acquired for prospecting operation, during which the geologists must direct their efforts towards proving whether or not a mineral prospect is worthy of commercial evaluation (Moon et al., 1995). Here, there should be a clear idea of the size of the deposit sought, the maximum depth of interest, and whether underground mining is acceptable (Moon et al., 1995).

Activities carried out during prospecting include mapping on 1:50,000 – 1:25,000 scale, linking maps with a Universal Transversal Mercator (UTM), satellite imaging, pitting/trenching, reverse circulation, and diamond drilling at 100 – 1000 m section at one level depending on the mineral type, core sampling, etc. (Haldar, 2018). The goal of prospecting is to establish a mining prospect. Gandhi and Sarkar (2016) assert that 'a

prospect is a potential ore occurrence which has been confirmed by geological, geophysical, and geochemical studies to the degree that it can be tested' .

(c) General Exploration: The general exploration is the initial delineation of an identified deposit. It involves mapping on a 1:25,000, 1:5000, or larger scale for narrowing down the drill interval along the strike (100 - 400 m) and depth (50 – 100m), analysis for quality assurance, borehole geophysical survey, etc. (Haldar, 2018). The purpose of general exploration is to establish the major geological features of a deposit and provide a reasonable indication of continuity and estimate with high precision the size, shape, structure, and grade of the ore. The activity of the general exploration ends with the preparation of broad order of economic or pre-feasibility or scoping studies.

(d) Detailed Exploration: This is conducted just before mine development. Work done at this stage include mapping at 1:5000 and 1:1000 scales, closely spaced diamond drilling a trial pit in case of surface mining, borehole geophysics, etc. Also, at this stage of mineral exploration, the rock mass quality classification is carried out using classification systems such as Rock Mass Rating (RMR), Geological Strength Index (GSI) and Q-system, which is essential for mine stability, planning, and preparation of samples for pilot metallurgical tests work. The mining lease/license is obtained at this stage to commence the mining phase in the life of the mine.

It must be noted (as shown in Figure 2.2) that exploration does not end at the commencement of the mining phase. Ongoing exploration is usually conducted continuously throughout the entire life of the mine to supplement the ore reserve as the reserve is being depleted.

Type of mineral discovery

According to Rudenno (2012), upon discovery of mineral occurrence through mineral exploration, depending on the stage of mineral exploration, the two main terms used in describing the inventory of minerals are ‘resources’ and ‘reserves’ (see Figure 2.3). The mineral occurrence is classified as a reserve if it is extractable or exploitable at a profit, or a resource if the potential of the mineral is known but it has not been established to be exploitable or profitable.

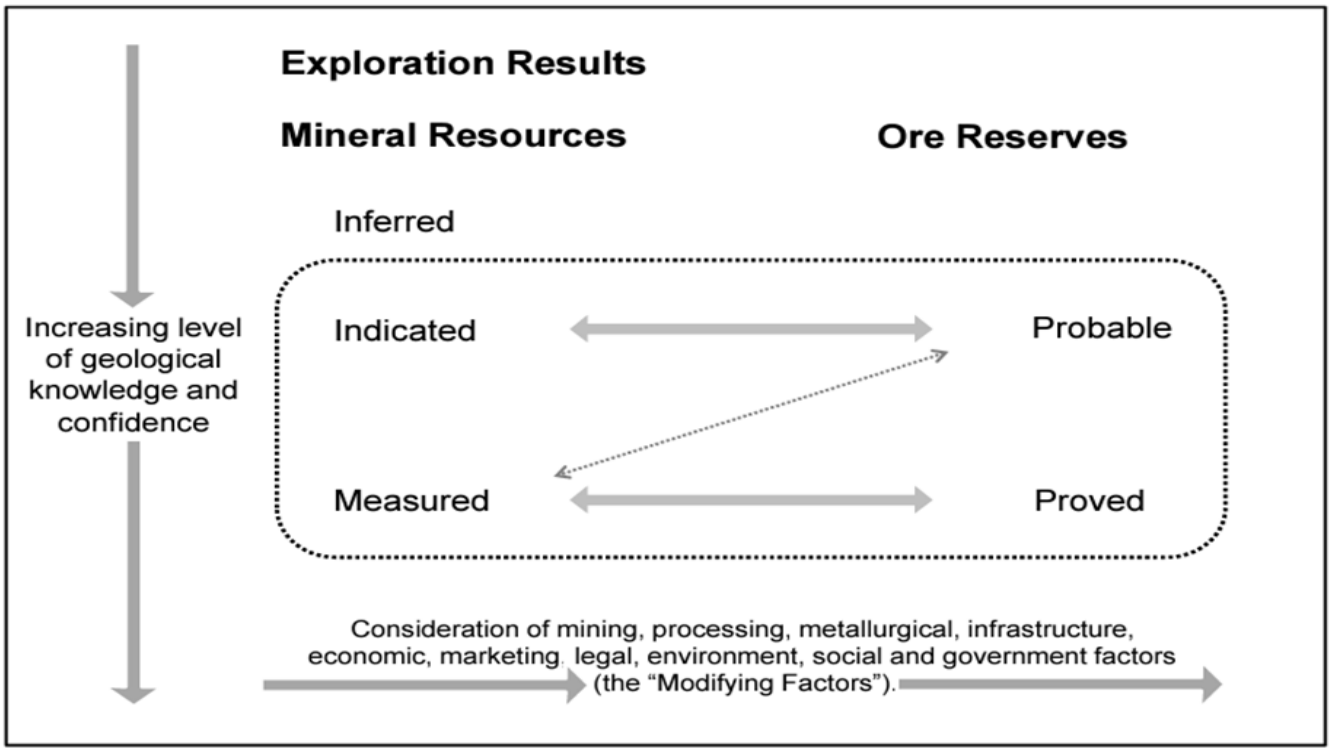

Figure 2.3. General relationship between exploration results, mineral resources and ore reserves (Source: JORC code, 2012)

Once the existence of a mineral resource has been identified through exploration (reconnaissance survey), the resource company would undertake a drilling program to define the resource. As the number of holes drilled increases, so too will the confidence level on the tonnage of the ore increase. Based on the level of confidence obtained through

the drilling program, the economic characteristics or viability of a mineral resource can be defined using the following:

(i) Inferred resources: These are the resources for which its tonnage, the grade, and the mineral content can be estimated with a low level of confidence and there are insufficient data to prove the continuity of the resource.

(ii) Indicated resources: These are the resources for which its tonnage, densities, grade, shape, physical characteristics can be estimated with a reasonable level of confidence and there are insufficient data to confirm the continuity of the resource, but the data is considered sufficient where the mineralisation's continuity can be assumed.

(iii) Measured resource: for a measured resource, the tonnage, densities, grade, shape, physical characteristics, and mineral content can be estimated with a high level of confidence and sufficient data are available to confirm the continuity of the mineralisation.

Summarily, Rudenno (2012) defined a resource as 'having reasonable prospects for eventual extraction. This definition considers that there would be part of the resource that would be of low grade and would be unlikely to be considered for mining. However, an ore reserve is defined as the economically mineable part of a measured or indicated mineral resource. In a nutshell, before a portion of a resource is classified as an ore reserve, the grade, tonnage, shape, density, physical characteristics, and all available data of the ore body must be estimated and a high level of confidence in these factors must be attained.

2.2.2 Feasibility studies

The goal of feasibility studies is to demonstrate that the mining project is economically viable if the project is appropriately designed, constructed, and operated (Rupprecht, 2004). A

feasibility study provides a definitive technical, environmental, and commercial base for the mining project and it is the key element leading to a decision to invest or not to invest (Rupprecht, 2004). More importantly, feasibility studies provide the opportunity to evaluate risk factors that may occur during the life of a project, or before its development. Thus, it assists in maximising the success of the venture (Rozman & West, 2001). The studies are designed to assess the potential of a project and to secure funding (White, 2011).

From the bank's perspective, Benning (2000) described a bankable feasibility study (BFS) as 'a detailed presentation of the technical, financial, and legal aspects of a viable project, on which the bank will perform its due diligence exercise' The BFS is considered "bankable" when the content is sufficiently detailed and supported by underlying data that enables a lender to make a judgment whether or not to consider providing finance based on the risk-reward relationship. The purpose of the lender's due diligence on the BFS is to: identify and mitigate risks; determine the risk-reward relationship to correctly price the debt; and develop appropriate funding and legal structure (Benning, 2000).

The feasibility study defines the ore reserves, the mining methods, the mineral processing techniques, and the scale of the project (Rupprecht, 2004). The information presented in a feasibility study usually reflects the stage of project development, the definition available, and the outcomes desired. Thus, a feasibility study can take the form of a scoping study, pre-feasibility study, or a full feasibility study.

Scoping study: This is the initial financial appraisal carried out at the very early stage in the project life and it is usually included in the elementary mine plan (Rupprecht, 2004). It is used when a very preliminary examination is required or when there are no specifics yet on the particular mining project (White, 2011). It may be used to evaluate whether to acquire exploration areas or to initiate/proceed further with a mining project. It is usually 30-60%

accurate and the evaluation can be conducted using mine layouts and factoring is known costs of a similar project conducted elsewhere.

The scoping study will provide a preliminary estimate which is reflective of the size of the proposed mine. An example of a scoping study carried out on the development of an artisanal and small-scale gold mining site conducted by PlanetGOLD (2020) reveals a total estimate of $89,730 for the installation of equipment, working capital, monitoring and maintenance, repairs, etc. This is in sharp contrast to a typical large-scale mine that gulps excess of hundreds of millions of dollars (Rudenno, 2012).

Prefeasibility study: This study is usually undertaken once a mineral resource has been identified. At this stage, one must be sure that the mining project is feasible and/or identify areas that require further detailed studies. Prefeasibility study usually has a level of accuracy of 15-30%. This study is applied to assess large pre-development expenditures e.g., test mining. It can be used as part of due diligence from a potential purchaser of the mining project. It can also be used to assess whether to proceed with full feasibility. The pre-feasibility study provides the first indication of the likely viability of the mining project.

Full feasibility study: A full feasibility sometimes called a definitive feasibility study (DFS) or bankable feasibility study (BFS) should demonstrate with reasonable confidence that the mining project can be constructed and operated in a technically sound and economically viable manner. Rudenno (2012) defines a full feasibility study as “a comprehensive study of a mineral deposit in which all geological, engineering, legal, operating, economic, social, environmental and other relevant factors are considered in sufficient detail that it could reasonably serve as the basis for a final decision by a financial institution to finance the development of the deposit for mineral production” .

A full feasibility study provides material or documents that can be used for raising money from banks or other sources. Typically, the study contains the ore reserves estimates, the scale of the project, the construction budget, schedule for the project, a cost estimate for operating and capital, market estimates, cash flow study, risk and sensitivity analysis, and contingency (Rupprecht, 2004). The accuracy of the full feasibility study is 10-15%.

Additionally, in very large mining projects where owners require a higher level of certainty ahead of a decision to proceed, the use of basic engineering within a feasibility study context as a predevelopment activity has become popular in recent years (White, 2011). The accuracy of the engineering design work for feasibility studies is better than plus or minus 10% (Rudenno, 2012).

2.2.3 Environmental Impact Study

Another important document used in assessing the viability of a mining project is the Environmental Impact Assessment (EIA) report. The EIA will typically detail the various alternatives to carrying out the mining operation and will document the various impacts for each alternative. The relevant impacts covered by the EIA include: any potential or actual change to the physical, natural, cultural, social and economic environment arising from the mining activity or proposal (Morrison-Saunders et al., 2015). Many African countries now require some form of EIA to be carried out prior to the commencement of major projects (Morrison-Saunders et al., 2015). In Nigeria, even though ASM activities are not considered a major project, a form of environmental impact study is usually required before the ASM company or cooperative can be registered and issued license. The document which is termed ‘Environmental Audit Permit’ is a replica of EIA, although obtaining this document is inexpensive and it takes less rigour to acquire compared with the more detailed EIA. The difference between the EIA and the Environmental Audit Permit is that while the owner of

the proposed mine conducts the EIA by himself and obtains approval from the necessary regulatory authority, the Environmental Audit Permit only notifies the government of the intention of the ASM operator to mine in the said location, and it allows the government's ministry of environment to assess the nature of the operation and its potential impact on the environment, with a view to forestall environmental hazard.

2.3 Estimating Credit Risks of an Investment

The quantification of credit risk is the process of assigning measurable and comparable numbers to the likelihood of default risk and the concept is a major frontier in modern finance (Ross, 2020). Credit risk is affected by factors ranging from borrower-specific criteria to market-wide considerations. The idea behind quantifying risk is that liabilities can be objectively valued and predicted to help protect the lender against financial loss.

There are no theories (to the author's knowledge based on a literature review) specific for predicting default in loans provided for an artisanal mining operation. However, some existing methodologies have been applied for credit risk assessment and for predicting the default of other small and medium scale enterprises (SME).

Financial institutions adopt different approaches in estimating credit risks to compute minimum capital requirements and to determine risk-weights for capital charges. The total available types of approaches used by financial institutions vary in the literature. Ahlberg and Andersson (2012) identified three major approaches for estimating credit risks and they include the "standardised approach", which uses external ratings provided by external rating agencies to determine risk-weights for capital charges. Another more advanced approach is the internal ratings-based (IRB) approach, while a third approach is an advanced form of IRB.

Lin and Ansell (2015) on the other hand grouped the methods used by bankers to estimate credit risks into two categories. First, the internal rating-based (IRB) credit models are used by banks to estimate their trading book exposures. For the IRB approach, the methods used include the probability of default, loss given default, and exposure at default. The second method which is used by corporate businesses is the Merton-type model, which would be further discussed in this section.

To evaluate credit risk, several variables are usually considered, and they measure the financial health of the borrower; the severity of the consequences of a default (for the borrower and the lender); the size of the credit extension; historical trends in default rates; and a variety of macroeconomic considerations, such as interest rates and economic growth.

According to the Basle II accord, loan risk measuring should be based on predictions of the Probability of Default (PD), loss given default (LGD), exposure at default (EAD), and effective maturity (M) (Behr & Güttler, 2007). To evaluate a borrower's credit risk, banks using the foundation internal ratings-based approach will be provided fixed values for LGG, EAD, and M by bank regulation authorities. PD on the other hand will be conducted by applying an internal rating system (Behr & Güttler, 2007).

2.3.1 Probability of Default

The probability of default (PD) expresses the likelihood that the borrower will not maintain the financial capability to make scheduled debt payments. The probability of default is usually estimated by credit rating agencies and other entities that issue debt instruments, such as corporate bonds. Generally, higher PDs correspond with higher interest rates and higher required down payments on a loan (Ross, 2020).

There are two approaches to modelling the assessment of default of companies, and they are Merton type models and accounting models.

2.3.1.1 Merton Model for Credit Risk

Merton-type models were designed for corporate businesses and are based on measuring the ratio of business debt and firm's assets and also the volatility of equity price. The quantitative modelling of credit risk, initiated by Merton (1974) reveals how corporate liabilities (debt and equity) can be priced and the probability of default can be estimated under some specific assumptions using a call option on the value of the firm's asset, developed from Black-Scholes model (1973).

Merton's model assumes that the market value of a firm's underlying assets follows a Geometric Brownian Motion (GBM) of the form:

$$dV_A = \mu V_A dt + \sigma_A V_A dW \tag{2.1}$$

Where V_A is the firm's asset value, with an instantaneous drift μ, and an instantaneous volatility σ. W is the standard Winer process.

The second critical assumption of the Merton model is that the firm has issued just one discount bond maturing in T periods. Under these assumptions, the equity of the firm is denoted by X_t, the book value of the debt at the time t, that has matured equal T.

The market value of equity, E is then described by Black-Scholes (1973) formula for call options,

$$E = V\,Nd_1 - Xe^{-rt}\,N(d_2) \tag{2.2}$$

Where $$d_1 = \frac{In(\mathrm{V_A}/X)+\left(r+\frac{1}{2}\sigma_\mathrm{A}\mathrm{V_A}\right)T}{\sigma_\mathrm{A}\sqrt{T}}$$

(2.3)

,

$$d_2 = d_1 - \sigma_\mathrm{A}\sqrt{T},$$

r is the risk-free rate, N is the accumulation density function of the standard normal distribution.

Based on the Black-Scholes-Merton model as shown in Lin and Ansell (2015), once V and σ_A are estimated, the distance to default can be calculated as

$$\mathrm{DD} = \frac{In(\mathrm{V_A}/X) + \left(r - \frac{1}{2}{\sigma_\mathrm{A}}^2\right)T}{\sigma_\mathrm{A}\sqrt{T}}$$

(2.4)

And implied expected default frequency (EDF), implied probability of default is

$$\mathrm{EDF} = N(-\mathrm{DD}) = N\left(-\frac{In(\mathrm{V_A}/X) + \left(r - \frac{1}{2}{\sigma_\mathrm{A}}^2\right)}{\sigma_\mathrm{A}\sqrt{T}}\right)$$

(2.5)

A typical example where Merton's model was applied in valuing risk in mining firms is the study of Moyen et al. (1996).

2.3.1.2 Accounting-based Models

Accounting models require the selection of appropriate ratios and accounting measures to act as explanatory variables for predicting default (Lin & Ansell, 2015). A series of models have been explored using accounting data to predict company default. One of the foremost accounting-based models can be seen in the study of Altman (1968) which suggested the use of the Multivariate Discriminant Analysis (MDA) approach to develop a default prediction

model known as Z-score. Also, Ohlson (1980) employed a logit model to derive a default risk model known as O-score.

The accounting-based method is based on the assumption that there is a relationship between accounting and financial ratios and the default of the business (Lin & Ansell, 2015). Altman and Ohlson have explored several variables that explain the default of businesses. Likewise, the study by Kanapickiene and Spicas (2019) discussed three basic financial ratios used in estimating the probability of default to loan repayment, and they include:

(i) Liquidity (current assets/current liabilities) ratio, i.e., the ability of the company to meet its current liabilities using its current assets.

(ii) Solvency ratios (equity/total liabilities) show how many times equity is higher than total liabilities; the lower the ratio, the higher the financial risk of the enterprise, i.e., big commitments that will have to be covered in the future.

(iii) Activity ratios sales/total assets: a higher value of this ratio indicates a higher degree of efficiency in the overall asset management.

Different authors have used varying financial variables to examine the credit risk of small companies. In empirical research by Spicas et al (2015) and Spicas et al (2018), a total of 101 different models of bankruptcy prediction and credit risk models were analysed, the following groups of financial ratios were found to be used in the development of these models: (i) ratios of profitability, liquidity, and expenditure level groups were most commonly used; (ii) the ratios of the groups of asset structure, solvency, and asset turnover were used less frequently; (iii) the ratios of tangible asset and capital market groups were used least.

Non-financial variables are equally important in examining the potential for default to loan repayment. Non-financial variables are ratios that show the solvency opportunities of an enterprise by the way of analysis of non-financial sources (Kanapickiene & Spicas, 2019).

Examples of non-financial variables used for evaluating credit risks are credit histories, indicators of litigation, temporary measures applied, behaviour in social networks, and other significant information. In the study of Kanapickiene and Spicas (2019) that examined the default risk of small companies in Lithuania, the probability of default was found to be dependent on two non-financial ratios: the average term of delay of outstanding debts and the number of valid arrests.

For artisanal and small scale mining, useful non-financial variables to evaluate creditworthiness may include social collateral; the formality or legal status of miners; financial or business planning skills; access to geologic assessment; land tenure; itinerant nature of miners; and service delivery due to remoteness of the mining area (Reichel, 2019).

An empirical analysis of reasons for defaults by small companies based on a unique data set on loans to German SMEs enables these companies to self-estimate their expected probability of default. Behr and Güttler (2007) posited that this is a good proxy for individual credit risk as measured by banks' internal rating systems and rating agencies. Behr and Güttler (2007) adopted a logit scoring model for the prediction of the probability of default by German small and medium-sized enterprises (SMEs) using a unique data set on loans in Germany. The scoring model adopted by Behr and Guttler (2007) helps SMEs to gain knowledge about their default risk, which can be used to approximate their risk adequate cost of debt.

Small companies usually require special tools for risk management, considering their peculiarities. The lack of data and difficulties in accessing the authentic database in small-scale companies results in lower quality data and lower reliability of the information. According to Abdullah, Muhammad, and Hwei (2006), this difficulty in accessing financial data and other information from SMEs is the reason why little research has been done in SMEs.

In recent years, it has been shown that the logistic regression models are the most popular and most efficient in predicting default and for overall credit risk assessment (Altman & Sabato, 2007; Behr & Güttler, 2007; Kanapickiene & Spicas, 2019 etc.). For a typical illustration of logistic regression models that predict credit risks of a small-scale enterprise, a recent study on investment risks in artisanal and small scale mining considers the following financial risks: “not yet able to scale”; “not yet able to deliver attractive returns”; and “the investment opportunity is too small” (Planetgold, 2020b).

2.3.2 Loss Given Default

Loss Given Default (LGD) is the amount of money a financial institution loses when a borrower defaults on a loan, depicted as a percentage of total exposure at the time of default (Tuovila, 2020). Financial institutions usually determine credit losses by analysing actual loan defaults. Quantifying losses requires analysis of several variables which an analyst would consider when reviewing all loans issued by the bank to determine the LGD.

For example, consider Bank-A lends $1 million to Mine-XYZ for investment, and the company defaults. The Bank’s loss is not necessarily $1 million. Other factors must be considered, such as the number of assets the bank may hold as collateral, whether a significant number of instalments have already been made to reduce the outstanding balance, and whether the bank makes use of the courts for reparations from Mine-XYZ. With these and other factors considered, Bank-A may indeed have sustained a lesser loss than the initial $1 million loans issued.

The most popular method analysts use for calculating LGD is the gross calculation, which does not take the value of collateral into account because academic analysts usually do not have access to the bond market. Thus, the values of collateral are unavailable, unknown, or unimportant (Tuovila, 2020).

For example, consider a small-scale mine operator that borrows $400,000 for mine shaft construction. He makes instalment payments on the loan for a few years and then faces financial difficulties. He defaults when the loan has an outstanding balance, or exposure at default, of $300,000. The bank took ownership of the mine and was able to sell it for $240,000. The net loss to the bank is

$$\$300{,}000 - \$240{,}000 = \$60{,}000 \tag{2.6}$$

The LGD is

$$\frac{\$300{,}000 - \$240{,}000}{\$300{,}000} = 20\% \tag{2.7}$$

2.3.3 Exposure at Default

Exposure at Default (EAD) is the total value a financial institution is exposed to when a loan faces default. It is the predicted amount of loss a bank may be exposed to when a borrower defaults on a loan. The EAD is a dynamic number that changes as the borrower repays the lender (Tarver, 2020). Banks usually calculate EAD for each loan and then use these figures to estimate the overall default risk of the bank.

Probability of Default (PD), Loss Given Default (LGD), and Exposure at Default (EAD) are used to calculate the credit risk capital of financial institutions.

A bank may compute its expected loss by multiplying the variable, EAD, with the PD and the LGD:

$$Expected\ loss = EAD \times PD \times LGD \tag{2.8}$$

2.3.4 Bank's Credit Ratings

Wallis (2001) described credit rating as the process of using a specific formula or set of rules to evaluate the creditworthiness of potential customers, in such a way that it evaluates the future loan performance of the customer. There are internal and external types of credit ratings. The external ratings are the ratings published by rating agencies while the internal ratings are developed by the lender.

According to Ahlberg and Andersson (2012), when rating a potential customer, banks collect both qualitative and quantitative data about a borrower. The quantitative information may include debt ratio, liquidity ratio, profitability, etc. Such data are collected from the financial statement and annual reports. Qualitative information on the other hand may include management quality, market situation, and legal form. They are usually collected during face-to-face interactions with the borrower. Ahlberg and Andersson (2012) argue that qualitative information needed often depends on the size of the business and the loan. Consequently, qualitative information will have a greater impact on the rating of the customer if it is a larger business or loan. A survey carried out by the European Commission in 2005 indicates that qualitative information account for 60% of the rating.

2.3.4.1 The five C's

The five Cs of credit is a system used by lenders to measure the creditworthiness of potential borrowers. The system assesses five characteristics of the borrower and conditions of the loan, intending to estimate the chance of default and consequently the risk of financial loss of the lender. Ahlberg and Andersson (2012) assert that the five C helps

banks' judgement of commercial loan applications. The elements of the five Cs as itemised in Beaulieu (1996) are character, capacity, capital, conditions, and collateral.

Character: refers to a firm's determination to repay debt. Concepts used to explain character are integrity, stability, and honesty. In practice, although it's called character, the first C more specifically refers to "credit history", that is, a borrower's reputation or track record for repaying debts. The information about a borrower's credit history usually appears on the borrower's credit report. These reports are generated by credit bureaus. Segal (2020) gave examples of three major credit bureaus – Experian, TransUnion, and Equifax. The credit reports generated by these credit bureaus contain information about how much a borrower has borrowed in the past and whether they have repaid those loans on time. The reports also contain information on collection accounts and bankruptcies. Information in these reports helps lenders to evaluate the borrower's credit risk.

Capacity: Management's ability to operate a business capable of repaying debt. Capacity is evaluated mainly through the analysis of financial statements; other factors (e.g., management's experience) are considered. In practice, capacity measures the borrower's ability to pay by assessing the borrower's debt-to-income (DTI) ratio and comparing the borrower's income against recurring debts. Prospective lenders calculate DTI by adding together a borrower's total monthly loan payments and dividing that by the borrower's monthly income. The lower an applicant's DTI, the better his chance of securing new loans. According to Segal (2020), many lenders prefer an applicant's DTI to not be more than 35% before approving an application for new credit.

Capital: The funds available to operate a business. Financial statements are a primary source of information about capital. Concerning credit risks, lenders consider the volume of capital the borrower puts forward. Lenders believe that a large contribution by the borrower

reduces the chance of default. For example, a borrower who can place a down payment on a home stands a better chance of receiving a mortgage. The size of the down payment also affects the rates and terms of a loan. A larger down payment results in better rates and terms (Segal, 2020).

Conditions: the conditions of the loan, such as the amount of principal and the interest rate also influence the lender in providing credit to the borrower.

Collateral: collateral here was described by Beaulieu (1996) as an alternative source of repayment, an explicit pledge required when weaknesses are seen in the other Cs. Segal (2020) argues that collateral can help a borrower secure loans since it assures the lender that if the borrower defaults on the loan, the lender can get something back by repossessing the collateral. Usually, the object that one is borrowing the credit for is used as collateral, for example, mortgages are secured by homes, auto loans are secured by cars. Thus, collateral-backed loans are sometimes referred to as secure loans, and they often attract lower interest rates (Segal, 2020).

The use of the five Cs of credit helps loan officers to acquire data in categories, that are of importance for the success or failure of given loans (Ahlberg & Andersson, 2012).

2.4 Bank's perspectives on mining projects risk assessment

This section discusses much on the nature of risks that banks look out for in formal mining projects. It also discusses how banks weigh risks in mining projects, quantify them, and adequately price them. Lastly, this section examines the perspectives of financial institutions on financing artisanal and small-scale mining operations.

2.4.1 Risk elements in mining projects

There are different origins of risks in the extractive industry with regards to banks' credit assessment. Benning (2000) identified eight different areas of risk that banks usually investigate when evaluating mining projects for possible investment. They include orebody risks, technology risk, operational risk, market risk, infrastructure risk, political risk, construction risk, and environmental risk.

The orebody or resource base is paramount and of great importance, as such, risk analysis usually prioritises this area for risk assessment. The reason is that the resource base is the one element that cannot be changed. If the resource base is flawed and the mineralisation is not in the ground in a quantity that warrants extraction, then there may be nothing that can be done (Rozman & West, 2001). For banks to be comfortable in investing in the mining operation of a particular orebody, the banks will want to see that an extensive exploration program has been undertaken and the results of such exploration have been adequately vetted. Banks would also ensure that the orebody has uniformity in grade and value, and the mining project has previously known exploitation (Benning, 2000).

While most studies agree that the orebody risk is the most crucial, Moon et al. (1995) argue that the greatest risk can be attributed to mine construction. The reason is that the construction phase may legitimately take several years, during which the loan is being used and no revenue is being generated. For this reason, mine owners usually require some form of guarantee from the construction contractor, to complete the project in a specified period or make penalty payments.

Another major form of risk that banks look out for is technology risks. Benning (2000) categorised technology risks into beneficiation, mining risk, and equipment selection. On beneficiation, banks desire the use of proven technology as a means of satisfying

themselves that there will be efficient recovery. The mining risks focus on an appropriate selection of mining methods concerning the characteristics of the particular orebody. For equipment selection, lenders would want to see the use of equipment that has a proven track record and reliable technical support and after-sales service. However, according to Benning (2000), potential lenders often underestimate risks related to equipment selection.

The market risk involves variation in the demand and supply scenario, lower metal prices than expected, and change in the foreign exchange rate which may affect the import and export of machinery and commodities (Haldar, 2018). Political risks include bureaucracy in licensing, instability of government, labour unrest, excessive royalties and taxes, and other regulatory issues (Haldar, 2018).

Another very important risk element is the operational risk, especially for projects at their early stage. Projects are usually vulnerable at the early stage as they suffer from ‘teething problems’. At this stage, projects are usually vulnerable because the debt burden is at the maximum, and delays in production build-up will affect cashflows to the extent that they can quickly put the project in jeopardy. According to Benning (2000), this is a major reason why bankers are more comfortable dealing with large mining companies with substantial financial muscle than smaller ones. In such a situation, the companies would likely not let their investment be liquidated or be taken over by the lenders but would rather inject more capital to get the project through the tough start-up phase. Risks relating to waste disposal is now considered to be gaining traction and is seen as central. As such, investors and lenders now look out for occupational risk and hazards that may arise from improper waste disposal systems in the operation. Mine waste can be generated during the mineral extraction phase (from overburden, waste rock and temporary stockpile of ore) and during processing (from tailings and other processing wastes). It is therefore essential that the

waste disposal systems are efficiently designed to prevent health and environmental hazards (Modoi, Stefanescu, Arghius, & Ozunu, 2009).

2.4.2 Weighing and pricing risks

The cash flow reflected in the feasibility study is usually prepared under ideal conditions without considering the future variations that may arise as a result of risks. Thus, it is important that the risks involved in a potential investment are examined and quantified, so that adequate safeguards are taken in advance to protect the investment– hence the need for risk assessment.

Once a potential risk has been identified, one common method of minimising the effect of risk is gradually altering the discount rates while valuating future cashflows (Haldar, 2018). The second risk-mitigating method is to adjust the cash flow by reducing the revenue by risk-free 10% over the base case with the discount rate unchanged. This will provide for a risk-adjusted Net Present Value (NPV). The third and most accepted method is sensitivity analysis (Haldar, 2018).

Like mine operators, banks that finance mining projects must also undertake standard Discounted Cashflow (DCF) analysis for appraisals. The only difference is the way they handle risk. Unlike mine planners, most banks do not increase discount rates (r) to reflect increased risk, instead, they use the cost of money for *r* and adjust the protection or coverage ratio, which is the net present value divided by initial investment (Moyen et al., 1996).

For this purpose, a typical rule might be,

$$\text{invest if: } \frac{\text{NPV}}{I} \geq 1.5 \qquad (2.9)$$

Where NPV is the net present value of future cash flows, and *I* is the initial investment.

Banks principally use cashflow methods in mineral valuation to determine the “bankability” of project development (Butler, 1994). This methodology is used to determine how feasible it is to finance projects, how much debt a project can comfortably support, and how sensitive their performance is to key areas. According to Butler (1994), this technique is particularly useful for project financing, where lenders look to a specific project’s cash flow, as compared to corporate financing where lenders consider a company’s overall balance sheet for security.

According to PlanetGOLD (2020), formal lenders/investors usually weigh the risks that investments carry. Lenders do this during the evaluation of investment by weighing the ability of the underlying project to manage its risk, against the expected return of that project. Benning (2000) termed this the “risk-reward relationship”. Where the perceived risks associated with the investments outweigh the return potential compared with other projects, they are unlikely to allocate funds for that project. In all, building a financial track record that demonstrates the ability to repay loans and provide evidence of reliable cash flow is required for projects to access commercial finance.

Risks can be both real and perceived. If a risk is perceived but can be managed or eliminated, then the real risk for that project is lower than the perceived risk. For example, a lender or investor may perceive that artisanal and small-scale mining is risky in some parts of Africa and make his judgment not to invest based on this perceived risk. However, investing in seemingly risky businesses has its own merits. PlanetGOLD (2020) argues that “those who invest when the perceived risk is higher than the real risk, secure an advantage

in gaining geographical or sector-specific expertise and accessing the best projects while their competitors choose to invest in more proven markets” .

2.4.3 Bank’s perspectives on risks in artisanal and small-scale mining

For artisanal and small-scale mining, few empirical studies have outlined the risk criteria used by formal lenders in this industry. Notably, a report by the United Nations Development Program (UNDP) in the year 2020, asserts that ASM is a nascent sector for formal investors. As such, there is little information available on the commercial viability of, or investment successes in ASM since the formal sector is not well acquainted with the sector (Planetgold, 2020b). Precisely, PlanetGOLD (2020) identified the following barriers confronted by intending investors/lenders in artisanal and small scale mining of gold:

(i) The lack of track record in the sector results in challenges in quantifying and managing risks;

(ii) The lack of specialisation within this investment sector means investing team is not sure how to assess the projects;

(iii) The relatively high cost of investing in the sector means the cost of due diligence may outweigh the potential returns;

(iv) A lack of demonstrated ability to scale financing solutions, worsened by the perception of the sector as being highly fragmented and informal;

(v) The lack of available data from pilot projects to prove quantifiable impact potential;

(vi) The shortage of clearly articulated investment needs and terms of engagement, and well-established intermediaries to present these opportunities; and

(vii) A lack of investment opportunities that match the large minimum-dollar figures of many investor portfolios which are currently beyond the capacity of artisanal and small-scale mining.

The previously-outlined points indicate that the primary challenge formal lenders have with the artisanal and small-scale mining industry is the lack of available data that can be used to quantify the level of risk in the sector vis-a-vis the potential returns in the operation. The unavailability of impact data on ASM makes it hard for investors to justify the reallocation of funds from other proven sectors such as agriculture, and formal or large-scale mining sector to it.

While there is almost a dearth of studies investigating risks of a formal investment in ASM, recently, there are few studies aimed at promoting investment and sustained development in the artisanal and small-scale mining industry. In this domain, some studies have explored mechanisms that can reduce some forms of risks in artisanal and small-scale mining. For example, Tichauer and De Tomi (2019), examine geological uncertainty in ASM. The study creates a matrix (Tichauer-DeTomi matrix) that assesses mineral exploration practice in ASM and indicates priority actions that can reduce geological uncertainty. The matrix is designed using costs, effort, benefits, and the level of implementation of mining legislation directives as criteria. By improving exploration practice in small-scale mining, the Tichauer-DeTomi matrix provides an exploration template that may help small-scale miners and investors to add value and sustainability to their mineral production projects.

In summary, the bulk of existing studies aimed at promoting investment in ASM have prioritised geological certainty, exploration best practices (Tichauer & De Tomi, 2019), and proof of the reserve (Marin, Seccatore, De Tomi, & Veiga, 2016; Seccatore, Marin, et al.,

2014). These studies prioritise mitigating geological risks and not financial risks in the ASM industry.

Most of the studies that explain the unavailability of formal lending or micro-credit scheme in the ASM sector draws assertions based on perceived risks by lenders. For example, the study of Hilson and Ackah-Baidoo (2011) asserts that 'failure to determine, beforehand, an appropriate rate of interest, the geological content of miners' concessions to gain some insight on the potential lifespan of supported activities, ways to collateralize commitments to repayment, and other methods for reducing lending risk have led to high levels of borrower neglect and loan defaults, in many cases resulting in abandonment of lending schemes altogether'.

Similarly, a recent study by Reichel (2019) discussed some perceived credit risks of artisanal and small-scale mining. These perceived risks are believed to be responsible for the apathy of formal external investors in ASM. The long list of risks includes the remoteness of mining areas which makes service delivery not profitable; the itinerant nature of miners; the lack of land tenure which doesn't provide for physical collateral; the often informal or illegal status of miners; poor financial and business planning skills; little assess to geological assessment skills and equipment which would allow identifying the scale and value of the resource and an anticipated guarantee of return on investment; and lack of social collateral. Chaparro Avila (2003) corroborated the argument in Reichel (2019) by attributing the difficulty of ASM ventures in obtaining financial resources to the following reasons: lack of mining rights; lack of real guarantees for the credit; uncertainty as to the potential of the deposit etc.

The above discussed perceived risks of credit in ASM remain unproven through empirical studies for them to be described as actual risks. Also, how these factors could contribute to

the inability of ASM operators to make repayments to loans received is yet to be investigated.

2.5 Conclusion

This chapter reviewed the literature, in particular the existing methodology for estimating the viability of a mine. It is noteworthy from this literature review that banks have specific methodologies for evaluating the viability of mining investment. This methodology involves due diligence of the proposed mine's feasibility study by the bank. The bank usually expects the mine's feasibility study to reflect a detailed exploration and ore reserve estimation – which is usually beyond what a typical ASM operator could provide. The unavailability of these detailed financial models put ASM away from the reach of formal bank investment.

Considering the peculiarities of ASM, perhaps banks must model credit risks for ASM separately from large-scale corporations. The importance of creating separate credit risk models for small-scale investments has been identified and tested in the literature through empirical study. As an illustration, following the "Basel Accord" that explicitly differentiates capital requirements between large corporations and SMEs, Altman and Sabato (2007) developed a credit risk model that is specifically for SMEs in the US market. Similarly, Behr and Güttler (2007) developed a credit risk model for SMEs in Germany.

A similar study in the mining sector, that developed credit-risk models specifically for ASM operations remains scarce in the body of literature. The findings from the review of studies on the unavailability of bank investment in ASM (such as Hilson & Ackah-Baidoo, 2011; PlanetGOLD, 2020, etc.) indicate that the apathy of banks to funding ASM activities can be traced to the inability of banks to price the risk of investing the sector. Thus, a financial model is proposed, that captures the peculiarities of artisanal mining operations and incorporates ASM-associated risks identified in the literature.

CHAPTER 3 METHOD OF EXPERIMENTATION AND ANALYSIS

This chapter presents an evaluation of the existing theory for predicting the credit risk of an investment with emphasis on the data that was collected to estimate the credit risks of a particular artisanal and small-scale mining (ASM) operation.

In this chapter, the methodology used by credit providers in evaluating creditworthiness for ASM operation is presented. Also, the data used by the credit providers to evaluate credit risks of ASM operation are discussed. Thus, the outcome of this chapter is to validate the existing theory of examining the viability of artisanal and small-scale mining operations.

In addition, this chapter outlines the data to be acquired from ASM operators to develop models that predict their creditworthiness.

3.1 Theories for analysis of credit risks

For an investment to be creditworthy, the credit risks associated with the investment must be acceptable to the lender. Quantification of credit risk involves assigning measurable and comparable numbers to the likelihood of default risk to loans. In the literature, the variables required for analysing credit risks can broadly be classified into financial and non-financial variables, as described in section 2.6. A large chunk of the body of literature focuses on credit risk prediction using financial variables. In such instances, default risks are computed based on the available data from the credit history and credit report of the loan applicant. However, for small companies such as ASM operations, studies have shown that non-financial variables particularly play key roles in influencing default risk. For example, Kanapickiene and Spicas (2019) observed that non-financial variables such as indicators of litigation and behaviours in social network critically affects the default risks of small companies. The adoption of non-financial variables for the prediction of credit risks is even

more important in ASM owing to the rudimentary nature of the occupation where cash flow records or proper documentation of productivity is often non-existent. Also, the unavailability of external rating agencies that can provide credit ratings for small companies in developing countries, creates a bottleneck in the use of credit reports for credit risk predictions for such operations.

Thus, to estimate default risks of ASM operations assessed in this study, the perceived risks identified in chapter one and two of this thesis have been streamlined to the following variables:

(i) the nature of the miner's practice (whether temporary or stable)

(ii) availability of land tenure, lease holdings, and mining rights which provides for physical collateral

(iii) the formal or illegal status of the operation

(iv) availability of detailed feasibility studies

(v) access to geological assessment skills and equipment which would allow identifying the scale and value of the resource and an anticipated guarantee of return on investment; and

(vi) availability of social collateral.

3.2 Method of data collection

To capture the credit-risk variables itemised in section 3.2, data was required for evaluation purposes. Since the study is a mixed form of research, data were collected through quantitative and qualitative methods of data collection.

3.2.1 Qualitative Research

The qualitative research was carried out on two groups of participants which are, ASM stakeholders, and formal lenders.

3.2.1.1 Group 1 – ASM Respondents

An account into the Nigerian ASM industry shows that there are different levels of actors in the industry. They consist on one hand, of legitimate license holders who employ workers and pay them on daily or monthly basis. On the other hand, are those who do not own licenses and are just itinerants scavenging through marginal deposits. This study did not cover the second group or the illegal miners, rather, it focused on legitimate small-scale miners who aim not only to improve productivity through improved mechanisation and obtain profits, but also enhance safety and health of its workforce.

For the purpose of the qualitative study, the list of registered mining cooperatives was obtained from the Nigeria Ministry of Mines and Steel Development, which is the government ministry that regulates and registers ASM cooperatives. From the list provided by the government ministry, a sample group comprising seven (7) group of stakeholders were selected through purposive sampling technique and were interviewed. The selection of participants was done with a view to ensure there is representation in each category of interest. Another criterion adopted in the selection process was that only educated respondents who are at either senior miners or stakeholders that have enough experience in order to provide answers on issues relating to credit access for their mining cooperatives. Thus, this group is comprised of ASM cooperatives' presidents, heads of ASM unions, and associations. For mineral types where there are no registered cooperatives such as sand and laterite, the union or association presidents and senior miners on the mining sites were interviewed. The respondents were interviewed with questions on credit risks of ASM operations and access to finance in the industry.

To ensure responses were not biased, the ASM stakeholders that participated in the study were recruited from across different mineral types, which are all the mineral categories where ASM operation exists in the country. The list of the respondents, their designation, and the number of respondents in each category are shown in Table 3.1. The study covered three states in Southwestern Nigeria - Ekiti, Ondo and Osun. These are areas where ASM activities in all the mineral categories are predominant.

Table 3.1. List of ASM interview groups

S/N	Mining type	Designation	Number of respondents
1	Industrial Mineral (feldspar)	Mining cooperative society president	1
		Mine operators	10
2	Gemstone	Mining cooperative society secretary	2
		Mine operators	10
3	Gold (alluvial)	Senior miners on site	6
		Mine operators	15
4	Gold (surface mine site)	Senior miners on site	2
		Mine operators	10
5	Sand (first location)	Miners' association chairman	1
		Mine operators	15
6	Sand (second location)	Miners' spokesman	1
		Mine operators	15
7	Laterite	Miners' union secretary	1
		Mine operators	11
		Total	100

The response of the ASM stakeholders to the research questions helps to guide in designing the questionnaire and identifying key variables to be included in the questionnaire for ASM operators, and also to develop the interview questions for the formal lenders.

To develop the interview sessions, an interview protocol was developed that captures the key study variables. The questions in the research protocol are shown in Table 3.2. The questions were designed to provide an understanding of the key challenges confronted by the research group concerning access to credit.

Table 3.2 Qualitative research questions

i) Are you a lone miner, or you belong to a cooperative?
ii) Is your operation licensed?
iii) Did you carry out ore reserve estimation before mining? Or what gives you certainty that the mineral that you are trying to mine is in the ground?
iv) Have you ever applied for any loan from a commercial bank to finance your mining operations?
v) If yes to (iv), was the loan granted? what were the conditions attached? and what are your experiences?
vi) If No (iv), why have you not tried to apply for bank loan?
vii) Have you applied for any loan from the Nigerian Bank of the Industry in the past?
viii) If yes to (vii) how was your experience?
ix) Are you aware that currently, there is a fund situated at the Nigeria Bank of Industry (BOI) specifically for artisanal and small-scale miners?
x) If yes to (ix), have you made attempt to apply and what are your perceptions about the fund?
xi) Generally, how do you fund your operation? Family sources or friends? Cooperative loans? Government support? External informal financing? International donors? or combination of some of the mentioned sources? Other sources?
xii) In your opinion, what are the challenges to obtaining formal financing for your operations?
xiii) Would you say your operation has been well funded?
xiv) What plans do you have on upgrading your operation to a more sustainable small-scale mining operation?
xv) Are you aware that there are credit risks which discourage investors such as banks from investing in ASM?
xvi) What plans do you have for mine closure, after you must have completed the mining operation in this reserve?

3.2.1.2 Group 2 – Formal Lenders

Initially, the study targeted few commercial banks. However, few of them, namely Guaranty Trust Bank, Zenith Bank, Stanbic IBTC bank, and Wema bank, all indicated that although they do provide loans for business entities in general, but not for ASMs, indicating that they do not have risk thresholds for them.Consequently, Development Finance Institution (DFI) was considered for the study. The foremost DFI in Nigeria is the Nigeria Bank of Industry (BOI). The mandate of the bank is to facilitate the entire process of accessing funds for SMEs (mining industry inclusive) right from pre-loan application. The bank provides access to funds for start-ups, SMEs, and large enterprises.

It is noteworthy, that the BOI partners with the government of Nigeria through an initiative termed Nigerian Artisanal and Small-Scale Miners (ASM) Financing Support Fund which is provided through a collaboration of the Bank of Industry and Federal Ministry of Mines and Steel Development (FMMSD). For this scheme, the BOI accepts loan requests from ASMs that have coordinated themselves into cooperative societies, and that are registered with the Nigeria ministry of mines and steel development.

At the time of visiting the BOI, the manager noted that although they have received several applications from ASM operators, none of the applications have been deemed creditworthy. Thus, the researcher requested the checklist containing all documents required and information required for an ideal application. This checklist as well as other information obtained from the unstructured interviews sessions with the bank were used to develop the questionnaire issued by the researcher to ASM operators to identify the key areas affecting the creditworthiness of the ASM operations.

3.2.1.3 Analysis of Qualitative Data

Qualitative research involves the use of data collection techniques such as interviews, recordings, notes, and observations. There are two models commonly used for analysing qualitative data: the hypothetico-deductive model and grounded theory. The hypothetico-deductive model involves the formulation of a hypothesis from an existing theoretical framework in a form that is falsifiable, then conducting a test on observable data where the outcome is not yet known. The outcome of the test will either validate or disprove the hypothesis. Grounded theory on the other way involves the application of deductive reasoning. It usually begins with a research question or collection of qualitative data, and as the researcher reviews the collected data, ideas and concepts begin to emerge. These ideas or concepts are termed “codes”, which can then be grouped into higher-level concepts and categories. These categories may form the basis for a new hypothesis and theory.

In this study, grounded theory was applied to develop ideas and concepts from the collected data to provide answers to the study objectives. After completion of data collection through interview sessions, analysis of the research data involves three main steps in line with grounded theory. These steps include:

(a) Coding text and theorizing: coding involves coding line-by-line from the very first line of the first interview to identify concepts. Theorizing here involves pulling these concepts together and relating to a larger more inclusive concept.
(b) Creating memos and theorizing: Creating memos involves a process by which the researcher writes out the concepts identified through coding. Writing memos helps in building theories.
(c) Integrating, refining, and writing of theories: This involves creating a theoretical model constructed around a central category based on the coding categories that emerge from the coded data.

Qualitative analysis tool

The interview sessions with Group 1 (ASM stakeholders) were transcribed and analysed using a qualitative data analysis software called ATLAS.ti version 9. The software helped to uncover and systematically analyse complex phenomena hidden in the unstructured data collected from the sample groups

To develop the research themes, the point of interest from each interviewee's response to each question is highlighted with a code. Similar codes are then grouped as code groups, which can then be regarded as the research themes. In all, ATLAS.ti helped to streamline discussions from up to fifteen (15) questions in the interview protocol into just six (6) research themes, which focus on a method for establishing mineral certainty, ability to obtain capital for investment, and plans to upgrade operations.

The following tools of ATLAS.ti were used for analysing the interview script in this study:

(a) Codes: The code function in ATLAS.ti was used to highlight and label key texts in the script that are of interest to the researcher. These labelled texts are hereafter referred to as codes.

(b) Memos: the memos used to create memos which are thoughts or insights of the research which he derives as he reads through the script.

(c) Network: Networks are created to link and show the relationship between entities such as quotations, codes, documents, and memos.

(d) Code co-occurrence table: This table shows the number of times a code is used together with another code in a particular statement signifying that there is a relationship between the two codes.

The analysis carried out using ATLAS.ti on the interview sessions with ASM stakeholders was used to develop the themes for the study which helped to develop Chapter 4 of this thesis report.

3.2.2 Quantitative Research

3.2.2.1 Questionnaire Design and Distribution

For this purpose, a well-structured research questionnaire was developed based on the data acquired from the BOI to elicit information from the primary participants which are the ASM operators on questions about the research problems, and selected ASM operators are required to fill the questionnaire appropriately. ASM operators were selected based on a random sampling technique. Southwestern Nigeria was purposively selected for the study. This region was selected because it hosts various types of minerals being mined through ASM operations. Thus, specific ASM mining communities were selected within the study location, for the study. To ensure responses were not biased, miners were recruited across different mineral types which include aggregates, gemstone, metallic ores, and industrial minerals.

After completing the design of the questionnaire, an application for ethics clearance for the study was submitted to the Ethics Committee of the Faculty of Engineering, Built Environment, and Information Technology (EBIT), University of Pretoria. Approval was obtained from the ethics committee for the study on the 7th of September 2021 (See appendix for the approval letter).

In order to compute a sample size for the study, it was essential to obtain an estimate of the entire ASM population in the study area. However, after consultation with government officers in the region, it was found that the government ministry primarily operates with ASM cooperatives and associations. As such, an accurate estimate of the entire ASM population

was not available. A representative sample was therefore selected and a total number of one hundred (100) respondents were approached for the research questionnaires. The study questionnaire has a total of eight (8) sections. Table 3.3 presents a breakdown of the components of the questionnaire.

Table 3.3 Components of the research questionnaire

Section	Title	Objective
Section A	Occupation	To elicit data on participant's (miner) primary occupation
Section B	Operation	To elicit data on the miner's method of operation
Section C	Licensing	To elicit data on the legality of the miner's operation
Section D	Reserve estimation	To elicit data on the availability of reserve estimate of the deposit and the knowledge of the miner in reserve estimation
Section E	Funding	To elicit data on the source of funding for the operation and whether proof of ore reserve is a requirement to obtain funding for the operation
Section F	Fund utilization	To elicit data on the specific projects for which the miner needs financial support in his operation
Section G	Loan requirements	To examine the ability of miners to meet minimum requirements for issuance of loans by formal lenders
Section H	Mine closure	To elicit data on the availability of plans for mine closure and reclamation

3.2.2.2 Analysis of Quantitative Data

Analysis of quantitative data on credit risks of ASM operation is carried out using binary logistic regression. This method of analysis is used because of its suitability for measuring individual credit risk. As an illustration, Behr, and Gutler (2007); Frerichs and Wahrenburg

(2003); and Plattner (2002) all used logit models to predict the default risk of German companies. Similarly, Kanapickiene and Spicas (2019) used logit models to predict the default risk of micro and small-scale companies in Lithuania.

The data compiled from the returned questionnaire from the dataset is analysed for the prediction for the deemed probability of default to loans for ASM operations. The data analysis is carried out using the R programming language and software environment. R is a programming language used by statisticians for developing statistical software and data analysis. The analysis for the quantitative data was carried out using the R language on the RStudio interface. Results from the R analysis were used to plot graphs and charts to explain the relationships between the variables in the study.

3.2.2.3 Validation of research instrument

Validation of the research instrument is important to ensure the reliability of the research instrument which is the questionnaire and the interview protocol. To validate the reliability of the instruments, the following steps were carried out.

Expert validation

To validate the content of the research questionnaire and the interview protocol, the research instruments were submitted to an expert to validate the content. The expert who validated the contents of the instruments is an expert in the field of artisanal and small-scale mining. Upon completion of the expert validation, copies of the research instrument were produced for the pre-test.

Pre-test

The purpose of the pre-test is to help develop and examine the accuracy of the research instrument, the questionnaire, which is to be used for obtaining data on the research objectives from the ASM operators.

For the pre-test, a sample of 30 respondents was identified outside the research group and each of the respondents was given the study questionnaire to fill out. The results of the pre-test were useful for the following purposes:

(a) To understand the average amount of time it takes to complete the questionnaire. The contents of the questionnaire were thereafter adjusted to ensure the questionnaire can be filled in at a reasonable amount of time considering the busy schedule of the miners.

(b) To understand the sections of the questionnaire that proves difficult for them to fill. The contents of the questionnaire were thereafter adjusted to ensure the questionnaire could be easily understood bearing in mind the low level of education of most of the miners.

(c) To understand how well the questions in the questionnaire provide insights into the problems of the research, and how it helps to achieve the objectives of the study.

3.3 Conclusion

This chapter examined the existing theory for predicting the credit risks of an investment. It then justifies the theory adopted in this study, which is the use of non-financial variables in predicting default risks in ASM operations. These non-financial variables include the nature of the miner's practice (whether itinerant or otherwise); availability of land tenure which provides for physical collateral; the legal or illegal status of operation; availability of feasibility studies; access to geological assessment skills and equipment which would allow identifying the scale and value of the resource and an anticipated guarantee of return on investment; and availability of social collateral.

Furthermore, the methods for the collection of data from the sample groups were discussed. A mixed form of research design which includes qualitative and quantitative methods of

research was adopted. The data collected are to be analysed using ATLAS.ti (for qualitative data) and R programming language and software package (for quantitative data and development of models for prediction of creditworthiness of ASM operations).

CHAPTER 4 RESULTS AND ANALYSIS OF QUALITATIVE RESEARCH DATA

As indicated, the target population for the qualitative study is from two groups: stakeholders in the ASM industry and formal lenders. The qualitative assessment on group 1 (ASM stakeholder) and group 2 (Nigerian Bank of Industry, BOI) of the study aims to provide answers for first and second questions for the research The result of the qualitative study on ASM stakeholders is presented in section 4.2 while the result of the study on the Bank of Industry is presented in Section 4.3.

4.1 Analysis of ASM stakeholders' interviews

To have diverse and unbiased views, respondents from different mining sectors were interviewed including those in industrial minerals, gemstone, gold, and sand, and laterite mining. The results of the analysis are presented in the following sections.

4.1.1 Reserve estimation

The review of literature in chapter two of this thesis report shows that efficient ore reserve estimation is a prerequisite to formal loan access. Lenders consider the reserve estimate as a vital requirement on which they do their due diligence. The assessment in this section examines the level of ore reserve estimation carried out by ASM operators. The respondents were asked how they (the miners) establish that mineral reserve is adequate at the deposit before they commence mining operations. The results of the analyses are highlighted below.

- At the industrial mineral cooperative society, the respondent who is specialise in the mining of feldspar indicated that they do not have the equipment to carry out elaborate ore reserve estimation. However, he stated that they do "explore" (search) for the mineral they are interested in, and once they have located the mineral in

sizeable quantity, they start mining operation. Still, he responded that there is no quantification of the mineral reserve at the site, they only follow the trace of the mineral using the exploration license they obtained from the government ministry.

- At the gemstone cooperative society, the respondents indicated that they gathered information on the potential of the resource from two sources, which gave them the courage to commence mining activity at the site. The first source was an ore reserve estimation carried out at the deposit initially by the former owner of the mine site before they took over. Secondly, they mentioned a government agency, the Nigeria Geological Agency, under the Nigeria Ministry of Mines and Steel Development, whose mandate is to carry out aerial and ground exploration for a mineral deposit, as a way of asserting the certainty of mineral deposit in each location. This agency conducts periodic exploration that provides details of the potential of the gem reserve at the location. This knowledge helps the miners to update their reserve estimates. The respondent stated that the agency last conducted reserve estimation at the location two years ago, and at the time of the interview, they were conducting another round of exploratory work at the location which was visible to the researcher when he visited the site. Thus, there is a documented reserve estimate at the gemstone mine site which is tenable for loan applications.

  However, the respondent further revealed that the exploratory work being done by the Nigeria Geological Agency is primarily to investigate the characteristics of a copper resource situated beneath the gemstone deposit. Since the copper reserve and the gemstone exist in the same location, reserve estimation of the copper reserve is tantamount to an estimation of the gemstone reserve. Thus, the gemstone miners believe they are the indirect beneficiary of the government exploratory work

on the copper resource situated in their gemstone location which is helping them to periodically update their gemstone ore reserve estimates.

- At the Alluvial gold mine, the respondent indicates that they usually carry out ore reserve estimation to establish certainty of mineral availability before commencing mineral extraction. It was revealed that the miners make use of an ordinary gold detector, which can only indicate the availability of the gold at the deposit but falls short of providing an estimate of the quantity of the ore deposit. To estimate the actual estimate of gold at the deposit, the miners usually visit the location, then they pick a sample area of say 20 square meters. Then they dig the sampled area to check what is in the ground with their own eyes. For example, if by digging the entire 20 square meters for 1hr, they were able to recover about 10gram or 20grams, then they can conclude that if they dig for five to eight hours, they would have recovered enough gold that would cover their investment costs and still provide some profit.
- At the primary gold mine site, some of the respondents indicated that they have a well-equipped system for computing their reserve estimate. The respondent, who is a manager at the mine, noted that the investors were not satisfied with the gold detector being used at the alluvial mine sites. So, they rented a scanner that provided details of the characteristics of the gold deposit including the tonnage and the depth. With this data, they were able to compute the expected lifespan of the mine and plan their mining operation accordingly.
- At the sand miner's association, one respondent described the sand mining business as a "black market" since no one is sure of what is in the ground. The respondent described the method the miners used to ascertain their ore reserve as follows:

> "*if you want to buy land now (for sand mining), when you get there, and you dig the land, you can check perhaps (the depth) gets to just 12 feet or it is not up to 12 feet, that way you will know if there is sand there or not*"

The response from the respondent concerning their method of carrying out ore reserve estimation indicates much of their reserve estimation is "guesswork" and the reserve estimation is not elaborate.

- At the sand quarry, most of the respondents indicated that the process of understanding how to measure the sand reserve is just like learning a trade. One respondent emphasized that, like every other business, in the sand mining business, it is important to know the quantity of sand in the ground before commencing mining operation at the location. The respondent explained the processes involved in reserve estimation in the sand mining business as follows: first, the sand miner goes into the bush/forest to search for prospective land rich in "sharp sand" useful for building construction or any other construction depending on the planned use of the sand. Once a prospective land has been discovered, the miner uses his jigger to dig into the sand to check the depth and also to assess the quality of the sand. The miner also examines the length and breadth of the reserve, to be sure it's adequate and worthy of investment. Once that is ascertained, then the miners proceed to negotiate the cost for the land with the landowner. The respondent asserts that having been in the business for many years, he knows a rich deposit just by sighting it.
- At the laterite miners' union, the respondent explained that their process of estimating reserve is similar to those at the sand quarry. He however noted that they do have some engineers who work with them as consultants who conduct periodic ore reserve estimation for them, especially when they want to obtain our lease.

A network developed from ATLAS.ti showing quotations from the seven (7) respondents on their method of conducting ore reserve estimation is shown in figure 4.1. It is observed from the assessment that out of the seven (7) ASM stakeholders assessed only two (2) have an efficient system of estimating ore reserve.

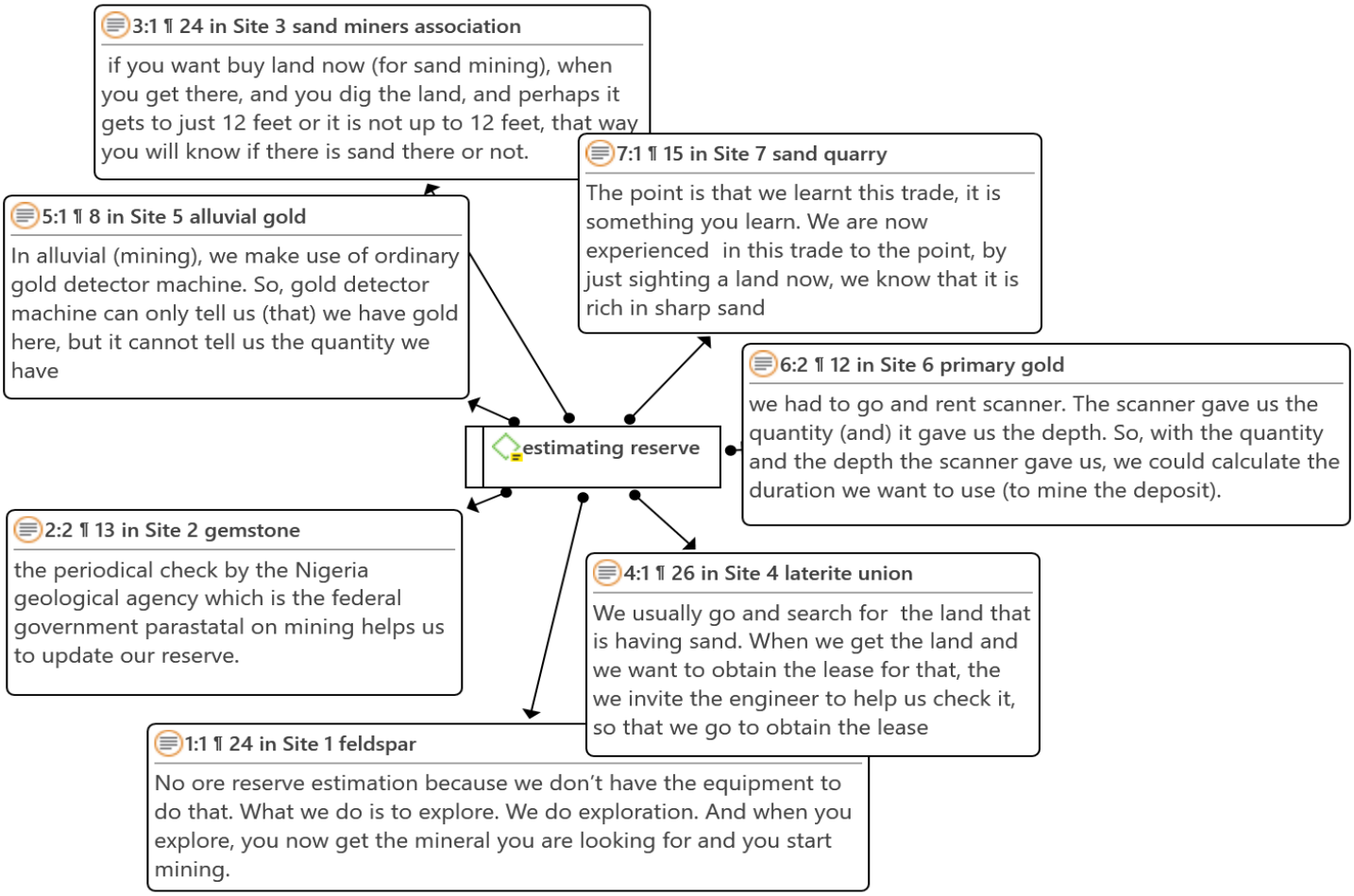

Figure 4.1 Miners' method of conducting ore reserve estimation

4.1.2 Credit risks in ASM

The perceived risks of lending to ASM operations were outlined in chapter one of this thesis report. Much of these risks relate to the perceived itinerant nature of miners. Some lenders consider these miners as nomads who move from one location to another in search of mineral deposits to exploit. This assessment examines the perception of the miners on the

itinerant nature of their occupation and the overall perceived risks of lending to ASM operations. The various responses of the respondents are presented in subsequent paragraphs.

- The respondent at the Industrial mineral cooperative society agreed that there are risks in lending to ASM operations. But he opined that the risk is only for those who are into gemstone mining operations such as tantalites, tourmaline, etc. He argued that such miner may be in a particular deposit mining today, and if he doesn't discover anything, the miner may move to another location. He called them "nomadic miners". He however argues that miners that are into industrial minerals are stable because the deposit is there and they can continue to mine and process.
- At the gemstone cooperative society, the respondent refuted the claim that gemstone miners are nomads who move from one place to another in search of a gem. He argues as follow:

  > *It is not genuine. It all depends on who they are referring to as the miner. Is it the miner with the jigger and the shovel? Or (is it) the miner that obtained a 5-to-10-year mining lease from the federal government that wants to abscond from his site? What we have in reality here is that the labourers that do the digging, are permanently staffed. That is just something that is not deniable but somebody…. For example, this hill has been in existence for the past 27 years, and by the special grace of God, as I have said earlier on, from the first generation of miners to the second generation of miners, we have been here for 27 years living in this place.*

- At the sand miners association, when asked about the perceived risks of credit to ASM operators, the respondent simply responded that they are not interested in bank funding as an association.

- At the laterite miners' union, the respondent argued against the popular notion of the inherent risks in ASM but he conceded that there may be some level of risk in the haulage aspect of the business. His brief response is shown below:

  I don't know of any risk as such, unless the tipper business, but not in the mining side of the occupation.

When asked specificifically about the perceived itinerant nature of artisanal miners, lenders believe they operate at one location today, and the next day they are at another location. The respondent who is the laterite miners' union president asserts:

That one cannot happen in our union. We are a union registered with the federal government. This is just one of our offices. So, we have a base, we are not people who do not have a location. The whole of this land (a vast land) belongs to us. We can't leave this land and run away.

- At the alluvial gold mine site, the respondent agreed that there are credit risks in their operation. He mentioned "land crash" as one of the risks they face in alluvial mining. When asked to explain what a "land crash" is, he gave the following explanation:

  For example, we start working for 10meters and excavating, and we are having steady production of gold, before we get to 20meter, we discover we can't find any gold again

The "land crash" can simply be explained as a condition whereby a miner invests his financial resources in a deposit based on the quantity of gold he was able to mine from the surface but as he continues the operation by excavating deeper, he discovers the gold reserve has been depleted.

The respondent provides further details on the risks to lending in alluvial mining of gold as shown below:

> *Yes. If someone is investing in you and that is the source of your credit and in the long run, as you are working, you now face the challenges of maybe land crash or flood, and if there is not much material at the site again, there is no way you can payback. Also, the market of gold is not stable, you may have the price today to be N1 before tomorrow it may become 50kobo.*

- At the primary gold mine site, the respondent noted that the only area of risk is in the price of gold in the international market which is not stable, he, however, argued that the risk in primary gold mining is minimal, especially since a detailed ore reserve estimation was carried out before the commencement of their mining phase.
- At the sand quarry, the respondent agreed that there are risks in their operation that can affect investment in the occupation. The respondent provides a possible risky scenario as follows:

> *If you are not well experienced in the occupation, you can buy a sand deposit that you would measure the thickness of the sand deposit, it would swell and it would seem convincing that the deposit is adequate. However, once you commence excavation, you discover there is no adequate sand there.*

While the majority of the respondents argued against the perception of ASM operators being itinerant as expressed in some studies such as Ofosu, Dittmann, Sarpong, and

Botchie (2020), most of the respondents (4 out of 7) agree with the perception of the economically risky nature of ASM operation, which supports the position in the literature (see, Perks, 2016; Eniowo & Meyer, 2020, etc.).

4.1.3 Access to formal funding in ASM

This assessment examines the level of access of ASM operators to formal sources of funding from financial institutions such as commercial banks, or development finance institutions such as the Bank of Industry (BOI). The findings from the study are shown below:

- At the industrial mineral mine, the respondent stated that they do not obtain investment capital from formal lenders. The respondent fingered the conditions attached to loans from formal lenders as the reason for their unwillingness to obtain such loans.

  The respondent was asked about the loan scheme from the Nigerian Bank of Industry that is designated for ASM operators. He asserted that their cooperative is aware of the loan scheme, but they are unwilling to apply because the BOI did not make the loan to be "friendly".

He narrated their experience with the BOI as follows:

> *"Why I said it is not friendly is that they said all of five of us here in the cooperative, they would give us N10 million. That is N2 million for each person. And the N10m would be attached to the equipment. So, what equipment are we going to buy with N10m? An excavator is not less than N30-35m. That is the least you can have, and that is the least equipment we need here. What we are using are shovel and digger, you can see what we are doing. So, if you now give five us N10m, and you said we should go and bring a Pro-forma*

invoice. What kind of Pro-forma invoice is going to bring? Is it tipper? We don't need a tipper. So, if we now go there, what invoice are we going to take there? Is it the excavator, that is N35million? Or what? So, we just feel that it is not friendly. If you want us to buy equipment, you give us something that can buy equipment".

Summarily, the miners argue that the fund provided by the BOI is too small to attend to their need which is equipment purchase. Since the miners stated that they do not obtain finance from formal lenders, they were asked where they obtain their funding. The response indicates that they obtain funding from personal savings, family, friends, and buyers.

The respondent asked to provide further details about the nature of funding obtained from buyers, explained as follows:

"The company that is using these materials to produce glass. Because what we are (mining) now is for glass production. And the company that is buying from us, sometimes give us a loan in advance, which they deduct as you supply".

When asked if the conditions of the loan offered by the buyers on the loan are fair, the respondent answered in the affirmative, and explained further as follows:

"(It is) very fair, because their own, they don't even say remove any percentage. The only thing is that when you supply, say you supply 30 tons, they remove money for 10 tons, they pay you money for 20tons. So that you can continue to produce, not like you pay all the debt at once and then you shut down. By the time you supply another 30 tons, they still deduct money for 10 tons, until you finish repaying all the loan"

The loan provided by the buyer is very beneficial for the continuity of the production of the miners. However, the miners noted that the buyers only provide loans at their discretion since they do not usually charge any interest on them. So, miners are not usually guaranteed of securing the loan any time they request.

- At the gemstone ASM cooperative, the miners revealed that they do not apply for loans from formal lenders because they believe such loans are very difficult for any ASM operator to access.

When asked if the cooperative has ever received any loan from the Nigeria Bank of Industry (BOI), the respondent answered "No". The respondent indicated that they are aware of the existence of the BOI and the loan facilities they give, but they have not applied because of their experience with other banks.

The respondent further argued that the financial support promised by government agencies as an intervention for ASM is a "political statement". He claimed that officers of these agencies have approached them severally on plans to support them with investment, even to the point where they (the miners) filled forms, but nothing comes out of it. As such, they now consider it a waste of time to apply for intervention programmes linked with the government.

Furthermore, the respondent argued that even if they apply and were offered the loan, the proposed ₦2million for each ASM operator by BOI would not affect their gemstone mining operation. He claimed that the cost of running the mine is beyond the loan facility. Concerning the BOI fund, the respondent claimed:

> *₦2million ($4,000) has no effect as far as this site (and) mining industry is concerned. It has no meaningful impact. The cost of running mining is beyond*

the loan facility. Then another headache there is that the repayment package has been something that has not been practicable. Like in the gemstone, I cannot speak of the industrial (minerals) but in the gemstone, you can work for a duration of two to three years without a win. How do you repay a loan that has two to three years of duration? It is something you cannot predict and up till present, there has been no designed mechanism to detect the depth, location, the angle of gemstone deposit. So how do you do that (repay a fixed tenure loan)?

The respondent was asked how the members of their cooperative society obtain funding since they cannot access formal sources. The respondent named cooperative loans. Within the cooperative, miners put their resources together to invest in the business. He also mentioned support from buyers. However, he noted that the support from buyers only comes from buyers of the minerals that are associated with the gemstone such as kaolin and feldspar. But financial support does not come from buyers of the gemstones because the buyers are from abroad. The respondent noted that the only support they receive from the government is for their reserve estimation.

- At the Sand miners' union, the respondent was asked if miners obtain funding from banks, his response reveals that miners typically do not take loans from commercial banks because of the interest rates.

On BOI, the respondent stated that they once approached the Bank of Industry for financial support for their members, but they were informed by the bank that they do not give loans to unions again, and some unions have disappointed them in the past.

The respondent revealed that the primary source of funding for their operation is from friends (associates) and cooperatives. He revealed that the only support they have received from the government is during the previous political dispensation when the then state government

- At the alluvial gold ASM operation, the respondent noted that he does not obtain investment funds from banks. He responded that he is not interested in using bank loans because the terms are not encouraging. He argued that alluvial mining is very risky, and due to this risk, he feels it is not wise to obtain a loan from banks. He further asserted that though he knows about BOI, he has never approached them for a loan.

When asked, if he knew about the loan scheme from the FG situated with the BOI, the respondent asserted that he is not aware, but he recalled that some time ago that some officers from Abuja (Nigeria federal capital territory of Nigeria) once visited his site, they inspect the site, measured the size of his mine area, asked about his tonnage, and asked him how he can sustain the site financially. He said they promised to get back to him, but he has since not heard from them. But he said he didn't even have the opportunity to apply for financial support to these teams. They promised to come for a secondary site visitation after which he would have the opportunity to request a grant. However, he has since not heard from them. This viewpoint corroborates the perception at the gemstone cooperative where the respondents opined that there is insincerity on the part of the government as regards the loan scheme.

When asked how he funds his ASM business, the respondent narrated that he was formally selling a truck business. However, when he decided to embark on the ASM occupation, he sold the trucks he uses and reserved two of them for his mining operation and that has been quite helpful for his haulage operation. Indicating that, contrary to the popular notion of the

live-and-go nature of ASM, this respondent was well-to-do financially when he ventured into mining. Still, he noted that sometimes whenever he has a financial crisis in his ASM operation, he benefits from informal financing arrangements, where buyers give him money ahead for gold, which he would eventually supply to the buyers upon completion of the mining operation. He noted that the rate he sells to the buyers is always at the market rate, contrary to the exploitative notion on informal financing arrangement in literature (see, Perks, 2016).

- At the primary gold cooperative, the respondent noted that they have never obtained a loan from any commercial bank in Nigeria or the bank of industry.

Their various sources of funding for the operation include family sources, foreign government support, and cooperative loans.

The respondent noted that the method used by the company to establish the ore reserve estimate of the mineral deposit (scanner, which provides the quantity and the location of the deposit) helps the company to be able to acquire funding for its operation.

- The respondent from a sand mining quarry who is a practicing artisanal miner was also interviewed. On whether he gets investment funds from banks, he responded that he does not use such funding. He insisted that instead of applying for such a loan, he would contact a friend who has funds to spare and is in the same profession. So, if he discovers a rich deposit but does not have the funds to pay the landowner, he can ask his colleague to raise him about half of the land cost and deposit it with the landowner as advance payment.

The respondent further revealed that he is neither aware of the existence of the BOI nor their loan scheme designated for ASM operators. He stated that his primary source of

investment funds is from friends and support from sand buyers. He noted that the buyers do not usually 'shortchange' them (the miners) in their dealings with them (the buyers). In other words, in this case, the miners are usually treated fairly in their dealings with the buyers.

To have a clearer picture of the perception of the sample group on the factors responsible for the apathy of ASM operators' informal loans, Figure 4.3 shows an ATLAS. ti network that links quotations of each of the respondents on the causes of lack of access of ASM operators to formal loans.

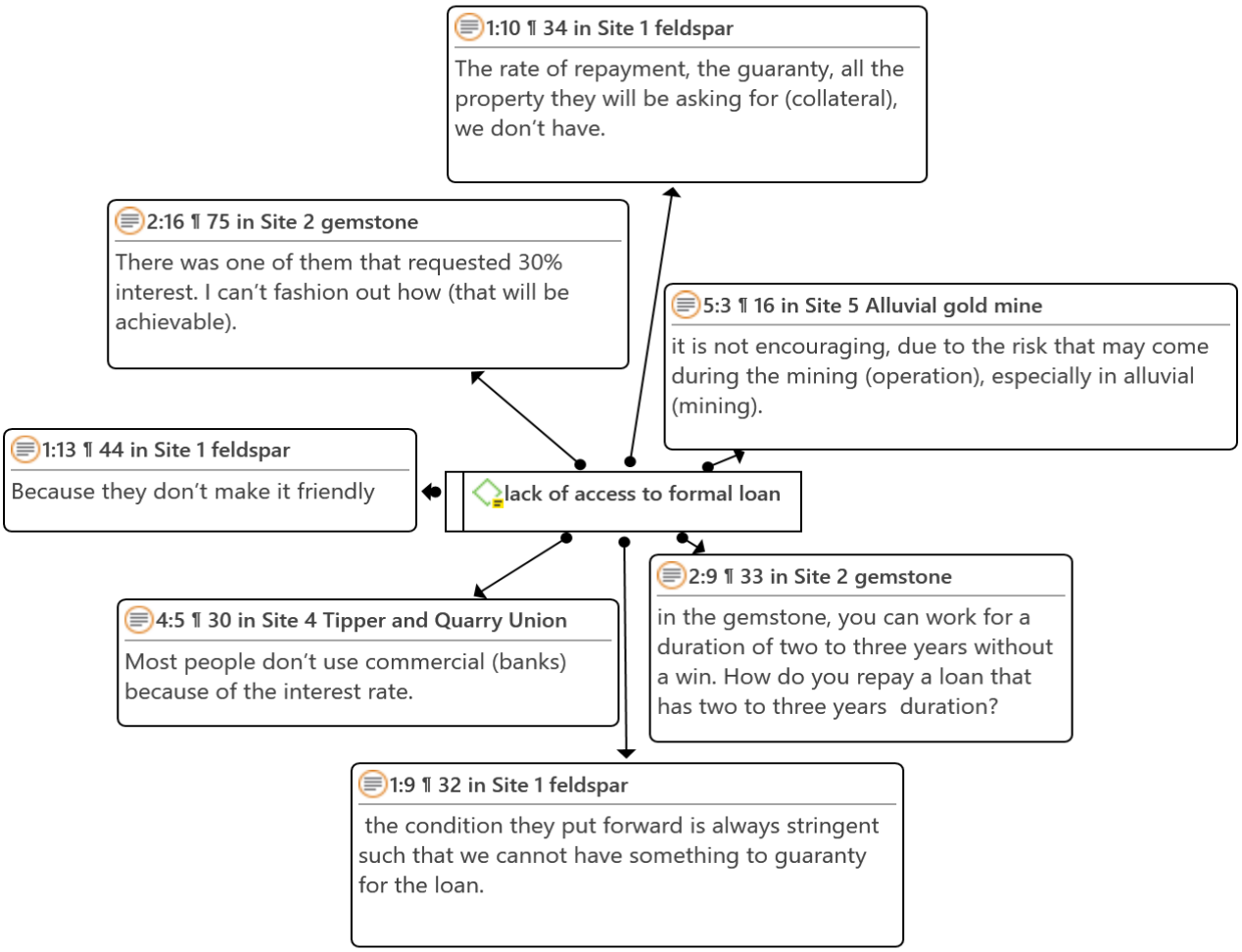

Figure 4.2 Miners' comments on causes of their lack of access to formal loans

4.2 Bank of Industry (BOI) credit risk management model

The Bank of Industry was visited in this study to understand the methodology used to manage credit risks by formal lenders who provide loans to ASM operations. To protect the bank from losses due to credit defaults, the BOI has a methodology for its due diligence which depends on the type of loan application to be submitted by the Borrower.

Based on interview sessions conducted with four senior employees of the solid mineral unit of the bank, the researcher was able to acquire information on how the bank captures the risk of credit provided for mining operations. While the model provided by the bank covers all loans granted to every form of mining operation, only the model used for small-scale mining operations is discussed in this thesis report. The following sections show the information gathered from the bankers during the interview sessions.

4.2.1 Loan request application

The BOI provides the loan applicant with a checklist which they are required to fill and submit with necessary documents. Upon submission of the application for loan request along with requisite documents, the BOI processes the loan application along with the checklist and the submitted documents.

4.2.2 Confirmation of availability of minimum mineral reserve

To confirm the availability of mineral deposit reserve on the ground, the BOI carries out the following due diligence:

(i) Liaise with the Ministry of Mines and Steel Development to verify the authenticity of the presented mineral title;

(ii) Review the geophysical survey report presented to establish the sufficiency of the reserve. For this purpose, the BOI engages the service of consultants who are competent in ore reserve estimation;

(iii) Ensures the credit coverage and the repayment period do not exceed the life span of the mine.

(iv) Visits the mine site to confirm the availability of the mineral resources on the ground and the existence of the mining operation. This visitation is carried out by the project officer from BOI.

4.2.3 Capital pricing to capture project risk

The BOI does not price each loan differently based on their peculiarities, instead, a blanket 5% interest rate is usually charged for loans issued by the bank. It must be noted, however, that this interest is considerably smaller than the interest rate charged by commercial banks in Nigeria. Additionally, the bank requires that the loan applicant presents collateral security that is reflective of the amount of loan to be issued. However, for small-scale miners, guarantors are used to substituting for the requirement for physical collateral.

4.2.4 Artisanal and Small-scale Mining Fund

ASM financing support fund is a new fund set aside for ASM by the Nigerian Federal Government and domiciled at the BOI. It is a part of ₦250,000,000,000 (about $500,000,000) intervention by the Nigerian government, out of which ₦200,000,000 ($400,000) is set aside specifically to be accessed by ASM operators.

Each ASM operator can only access up to ₦2,000,000 (about $4,000). To access the loan, the ASM operation is required to be registered as a mining cooperative and can only access the loan through his cooperative society. In addition to this requirement, the following conditions need to be met before the loan can be granted.

- The Mining cooperative must present a bank statement
- The president of the cooperative will be held responsible in case of default

- The interest rate of 5% would be charged on the loan
- A processing fee of 0.5% of the principal amount (non-refundable) is to be charged for every loan application
- The bank statement of the cooperative society must be submitted with the application. The statement must show that the cooperative has been in operation for a while. This requirement thus indicates that the BOI loan is not for start-ups. BOI only finances brownfield mining operations that have been in operation 'at least for a while' before seeking loans.
- Since collateral security may be difficult for artisanal miners to provide, they are required to instead present a guarantor who must certify any of the following conditions:
  (i) Civil servant, level 12 or above, whose service must not be less than 28 years, and must be 54 years or above; or
  (ii) Professionals, such as a certified Medical Doctor, a Lawyer, or any other professional working in 'blue-chip companies such as oil companies, telecommunication companies among others.

Additionally, loan applicants from BOI must positively attend to the following questions:

➢ **Market**

As part of the requirements, each applicant is to provide the following market-related information:

i. Product offering (What end-product will be produced)
ii. Target customers
iii. Value propositions (what are the key selling points)
iv. Strategies for generating revenue

- **Eligibility Criteria**

i. Is the promoter Nigerian?

ii. Is the business incorporated/registered?

iii. Do you have the required operating license with at least three (3) years remaining lifespan e.g., Mining lease, Quarry lease?

iv. Do you possess evidence of authority from the mining license owner to carry out mining activity? (Applicable to ASMs without mining licenses).

v. Do you have requisite documented permissions to operate under the ASM mining category?

vi. Do you have a factory or a mining site to operate from?

4.2.5 Scoring Models and Credit Ratings for ASM Credit Risks

The BOI generally does not have a scoring model that examines the default probability of lenders. Also, the BOI does not engage the services of credit rating agencies that could provide ratings of potential lenders to the bank. When asked, the managers of the solid mineral division of the bank responded that they are working towards engaging credit rating agencies to advise the bank on the risk potential of lenders, but such an arrangement does not exist yet.

4.3 Conclusion

This chapter presents the results of the qualitative research carried out in the study. The qualitative study comprises two sample groups which include ASM stakeholders and formal lenders. The investigation carried out on the ASM stakeholders sample group aims to examine the perception of ASM stakeholders on the credit risks and access to formal funding in ASM operations. On the other hand, the investigation carried out on formal

lenders aims to identify the methods used by formal lenders to estimate the credit risks of ASM operations.

The ASM stakeholders recruited as participants in the study comprised of presidents of miners' cooperative societies, chairmen of miners' unions and associations, and miners' spokespersons. To ensure the opinions expressed in the research are not biased, ASM stakeholders were engaged from different mining and mineral types including alluvial gold, surface (primary) gold, sand, laterite, industrial minerals, and gemstone mining. All respondents in the study agreed to participate in the research free of any form of charge.

The interview sessions with the ASM stakeholders focus on three major study themes which cover reserve estimation in ASM, perception of ASM operators on the credit risks of ASM operations, and access to formal lending in the industry. The opinions of the respondents were described. The result of the assessment shows that while some of the miners have well-documented reserve estimates, some miners only use insights based on their experience on the job to predict the estimates of ore reserve. Most of the miners agreed that the ASM operation is quite economically risky, but they argued against the perceived itinerant nature of ASM operators. To present a clearer picture of the respondents' opinions, the ATLAS.ti network of the quotations of the respondents was shown. A code co-occurrence chart was also displayed that shows the codes that co-occurred in the analysis.

The assessment on formal lenders was carried out at the Nigerian Bank of Industry (BOI) which is a bank that is designated to provide loans for small-scale operations such as ASM. The assessment at the BOI covers the requirements for ASM loan applications, methods used by the bank to confirm availability of minimum ore reserve, and methods for pricing the loans issued that captures project risks.

CHAPTER 5 RESULTS AND ANALYSIS OF QUANTITATIVE DATA

The result of quantitative analysis of data acquired from ASM operators on the creditworthiness of their operation is presented in this chapter. The quantitative analysis aims to provide answers for two of the research questions, which are

- *What model can be developed, using the knowledge of ore reserve, to predict access of an ASM operation to a formal fund?*
- *What models can be developed to predict that an ASM operation is creditworthy using the credit risk variables in the real-life case study?*

To attend to these research questions, data on credit risk variables were collected from formal lenders in the banking industry (discussed in chapter 4) and ASM operations were assessed to estimate how creditworthy their operations are. This chapter is divided into two sections which include descriptive statistics and inferential statistics.

5.1 Descriptive statistics

A descriptive statistic is a summary statistic that quantitatively describes or summarizes features from a collection of data. Descriptive statistics is the process of using and analyzing such statistics. In this study, the descriptive statistics carried out fall into three categories: demographic characteristics of the respondents, assessment of eligibility for a formal loan in the Nigerian Bank of Industry (BOI), and assessment of reserve estimation in ASM.

5.1.1 Demographics

(a) Occupation

The study comprises those who have ASM as their source of livelihood. However, as has been shown in the literature, many ASM operators usually rely on other secondary means of livelihood to compensate for the low level of income in ASM. The possible effect of this is that such ASM operators are considered as itinerant miners who jump from one occupation to the other, which is considered a form of credit risk.

Thus, the ninety-six (96) respondents were asked, “Do you have another occupation, apart from Artisanal and Small-scale Mining (ASM)?”. The result of this survey as shown in Figure 5.1 reveals that 34% of the respondents work as ASM operators alone while 66% do have other occupations which they use to complement their earnings in ASM.

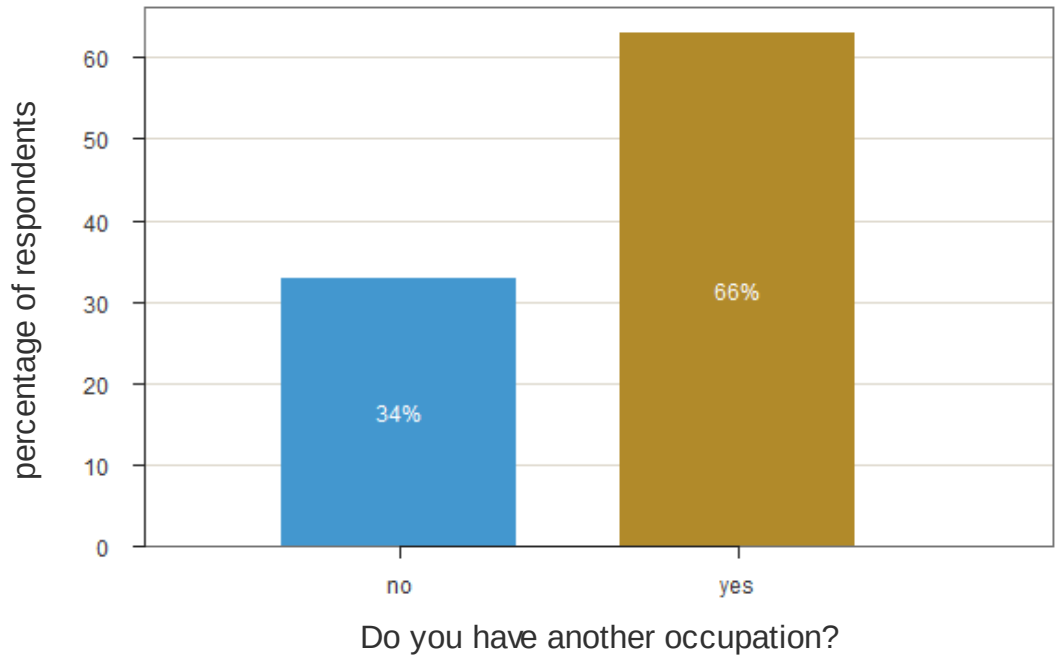

Figure 5.1 Respondents with other occupations

The respondents who indicate “yes” that they do have other occupations were further asked to indicate the nature of their other occupations. The result of this survey as shown in Figure 5.2 reveals that 19% of the 66% of the respondents who have other occupations work as artisans, 29% are small business owners, 1% are into consultancy, 1% are Drivers for companies, 3% are employees for other establishments, 44% are into farming and the remaining 1% are public servants. This result indicates that a larger percentage (44%) of the respondents who have other occupations combine farming with ASM operation.

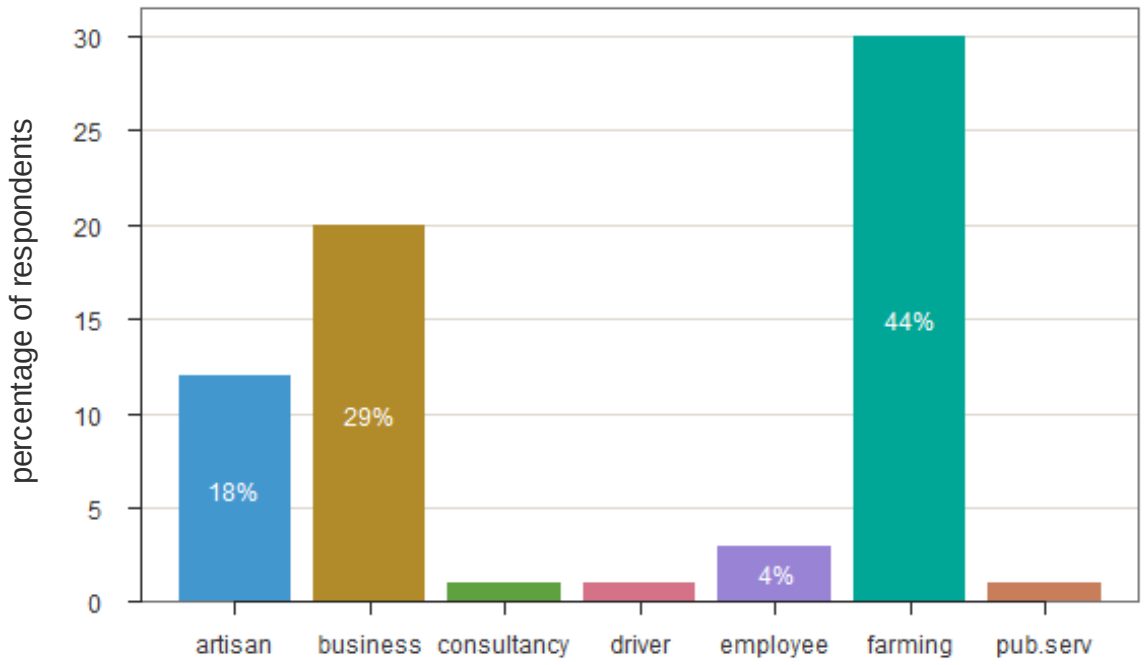

Figure 5.2 Other occupations of respondents

(a) Mining Type

The survey on the form of mining carried out by the respondents shown in Figure 5.3 indicates that 3% of the respondents are into alluvial mining (mostly for gold), 74% are into various forms of surface mining operations while the remaining 23% combines various forms of mining which may include any two or three of underground, surface, or alluvial mining (this is denoted as “multiple” in the chart).

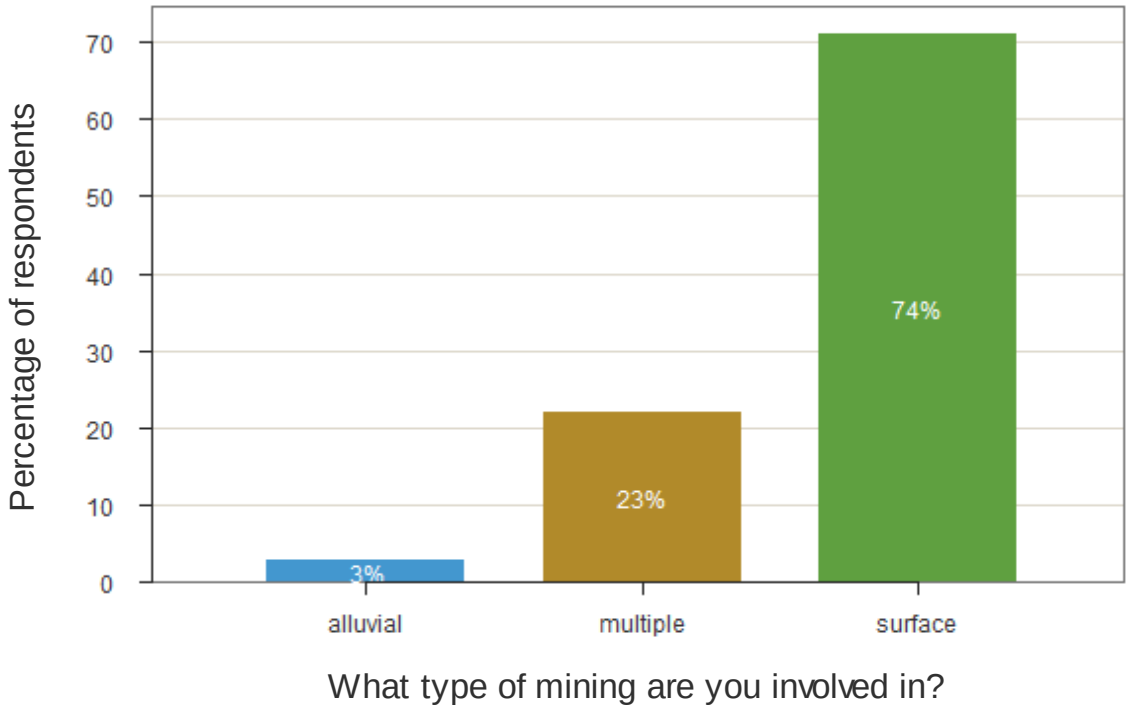

Figure 5.3 Respondents’ type of mining activity

(c) How miners operate

To understand how the respondents operate, figure 5.4 shows that 54% of the respondents work as employees in ASM firms, 36% work in a group with other individual small-scale miners, and another 10% work as lone miners.

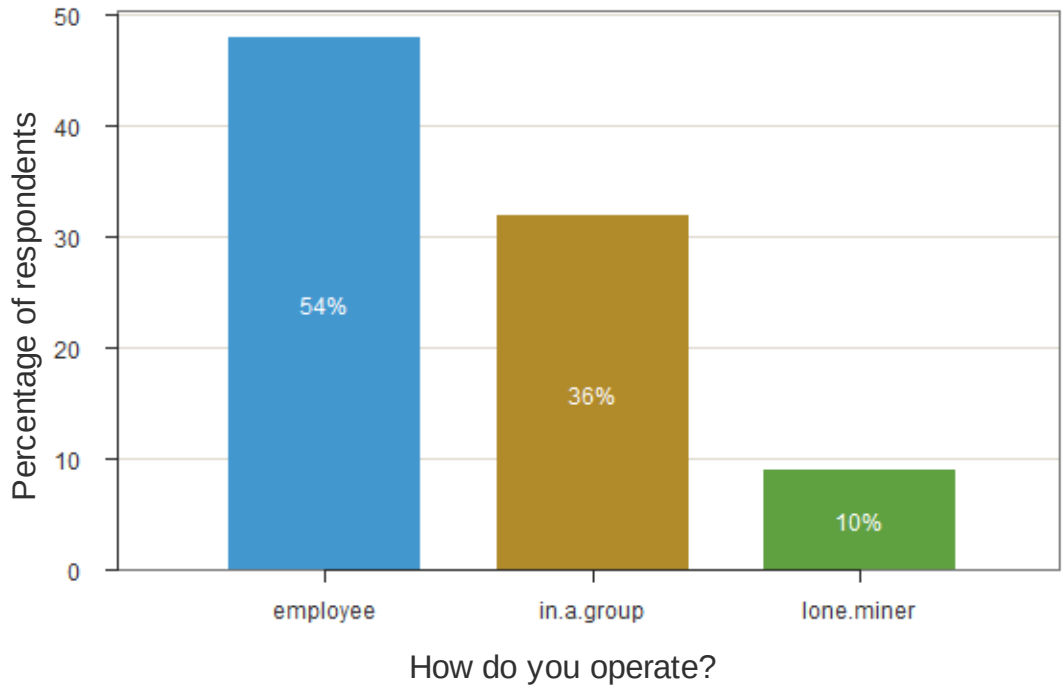

Figure 5.4 How respondents operate

To better understand the distribution of the nature of mining operations carried out by the ASM operators, the horizontal bar chart in figure 5.5 shows a cross-tabulation of mining type against how miners operate. The chart shows that out of the forty-eight (48) miners who work as *employees* in ASM companies, forty-seven (47) of them, representing 97.9% practice surface mining operations, one (1) representing 2.1% practice alluvial mining while none engage in multiple forms of mining practice. Out of the 32 miners who *work in a group* with other miners, six (13) of them, representing 40.1% practice surface mining, one (1) representing 3.1% practice alluvial mining, and fifteen (18) representing 56.3% work in multiple forms of mining. Out of the nine (9) miners who work as *lone miners*, one (5) representing 55.6% practice surface mining, one (1) representing 11.1% practice alluvial mining, and the remaining three (3) representing 33.3% practice multiple forms of mining.

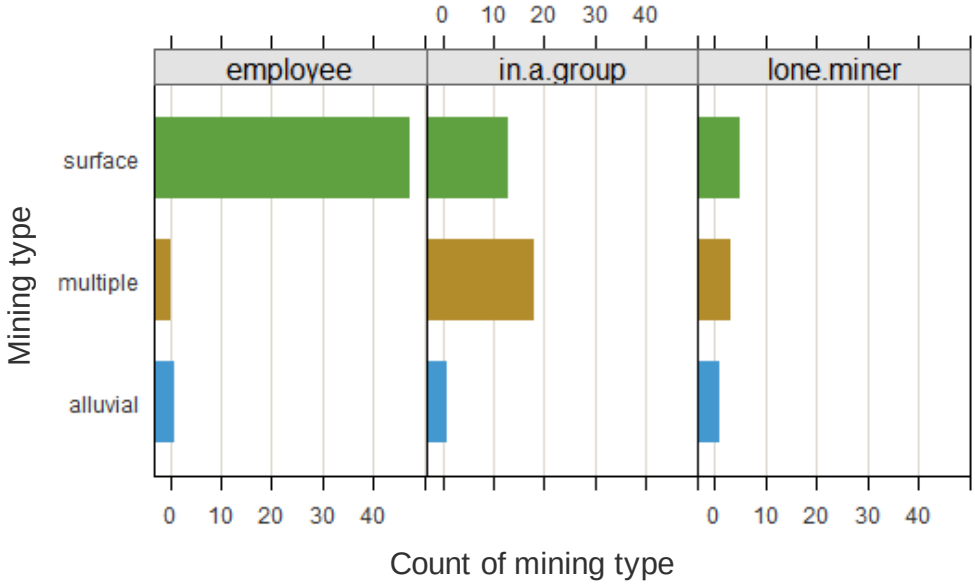

Figure 5.5 Crosstab of mining type by how miners operate

(d) Years in operation

The assessment of the number of years for which each respondent has been in ASM operation is shown in figure 5.6. The chart shows that the largest percentage, 27%, of the respondents have been in ASM operation for over 10 years, indicating that a large percentage of the respondents are experienced ASM operators.

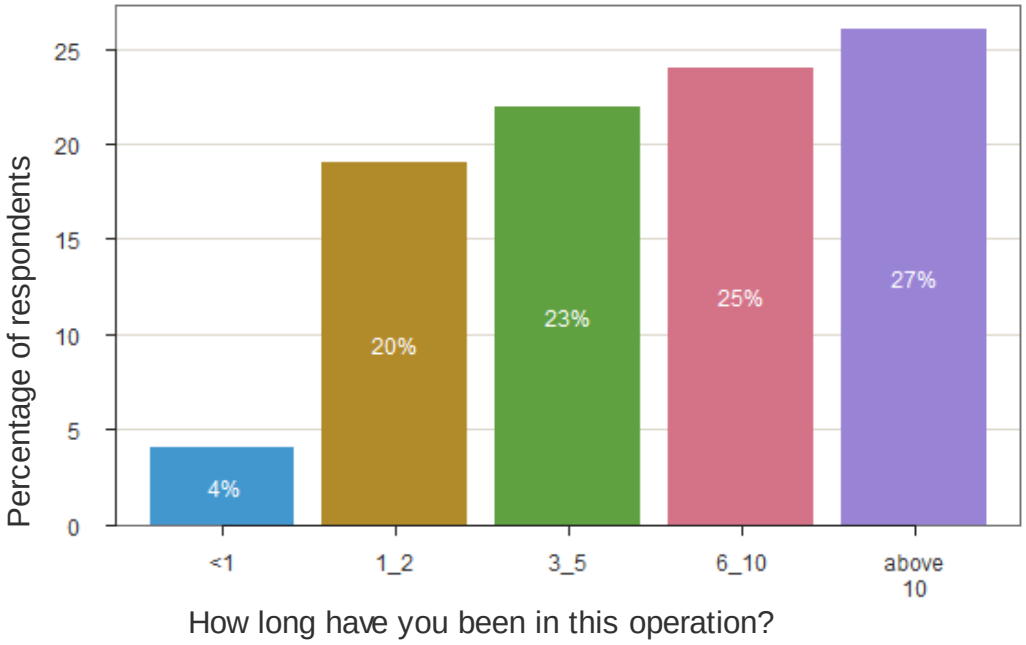

Figure 5.6 Years of operation of respondents

5.1.2 Eligibility for BOI loan

This assessment is carried out to examine the overall eligibility of the ASM operators for the loan issued by the Nigerian Bank of Industry (BOI). The variables used to estimate the eligibility was obtained from the interview sessions with the bank officers at the BOI and they include the ability to pay the minimum interest rate required, years in operation to show whether the mine is a greenfield or brownfield, proof of reserve, miners' method of operation, miners' membership in a government-approved mining cooperative society, availability of valid mining license, availability of guarantors, and availability of feasibility report. The results of this survey are presented as follows.

(a) Availability of valid license

The assessment of the percentage of the respondents who have valid mining licenses to operate shown in figure 5.7 reveals that 57% of the miners do not have valid licenses while only 43% have valid licenses. However, a chart of valid licenses with that of how miners

operate shown in figure 5.8 reveals that the majority (44%) of the miners who do not operate with licenses, work as “employees” in concession spaces under ASM companies. Further investigation by the researcher indicates that while the miners may not be aware, this ASM company does have licenses that span their entire concession spaces which cover the smallholder miners. Thus, since what the BOI requires as proof of licensing is only “evidence of authority from mining license owner for the artisanal miner to carry out mining activity on the mining area”, then the 44% of miners who work under ASM companies as “employee” can be added to the 43% who stated in their responses that they have licenses, making a total of 87% of the respondents who operate with licenses.

A further assessment shown in Figure 5.9 shows a pie chart of the various licenses being used by the miners who operate with licenses. The results show that 10% uses Mining Lease (ML), 8% uses Quarry Lease (QL), 75% uses Small-scale Mining Lease (SML) and 8% uses Exploratory License (EL). An exploratory license is meant to be used when the mine site is still at the exploratory stage meaning it has not started full operation. Thus, it is not useful to apply for a loan in a brownfield mine site that is already producing. Therefore, 8% of the respondents who operate with EL are not eligible for the BOI loan. This implies that the percentage of the miners who are eligible for the BOI loan based on the availability -of license criteria is 86% minus 8% who use EL, giving a total of 78% of the miners.

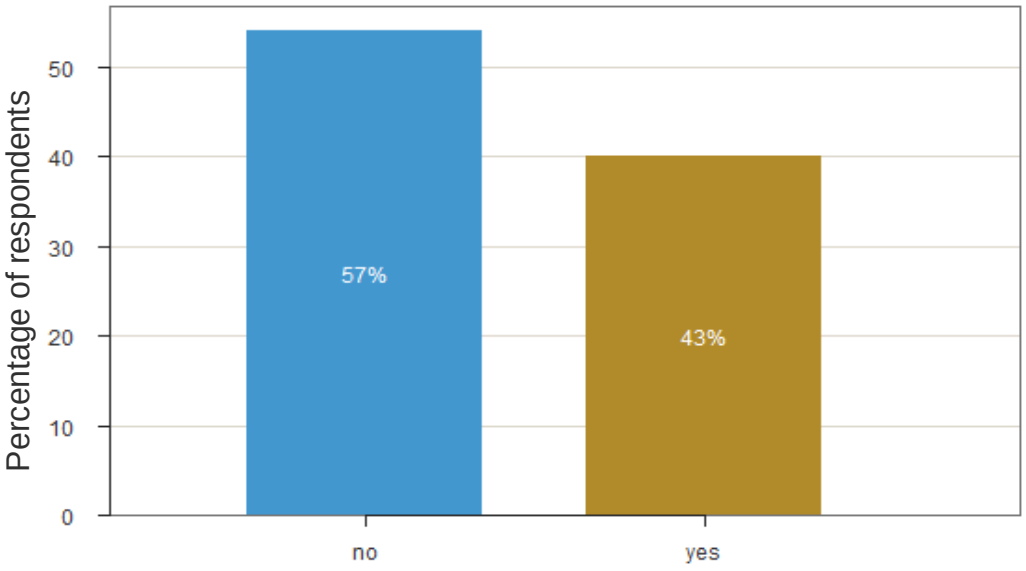

Figure 5.7 Respondents with valid licenses

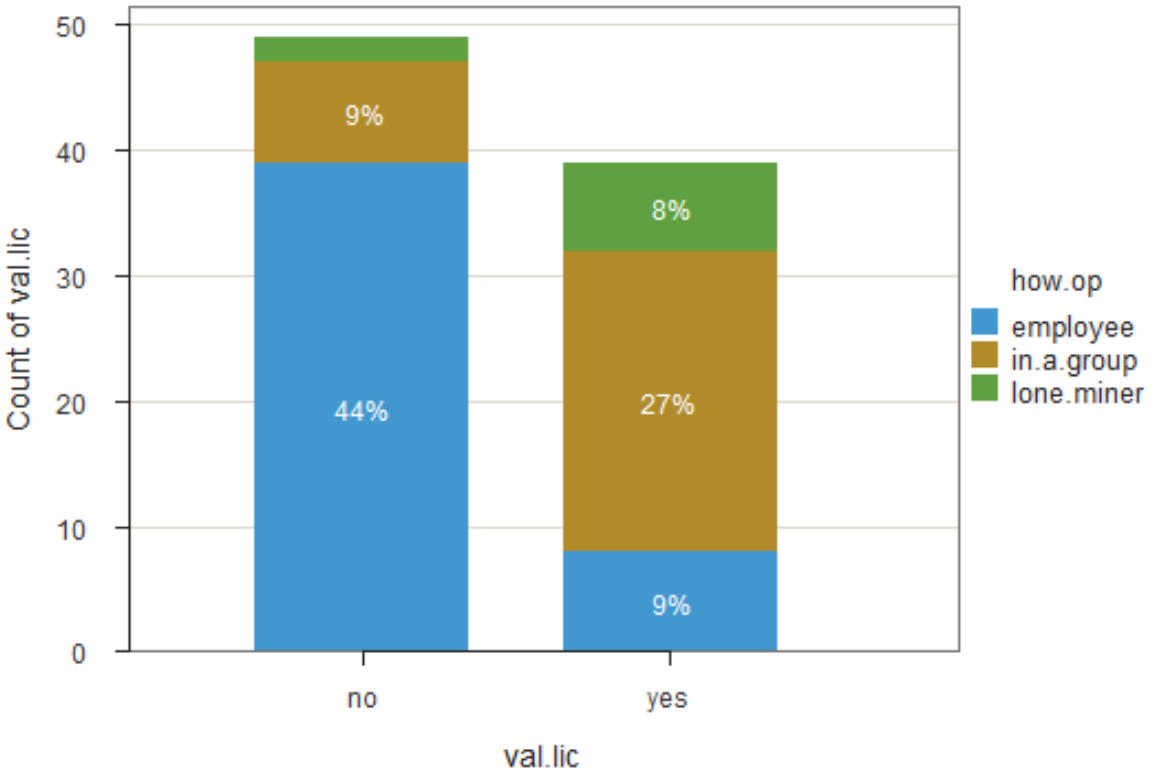

Figure 5.8 Respondents with valid licenses by how miners operate

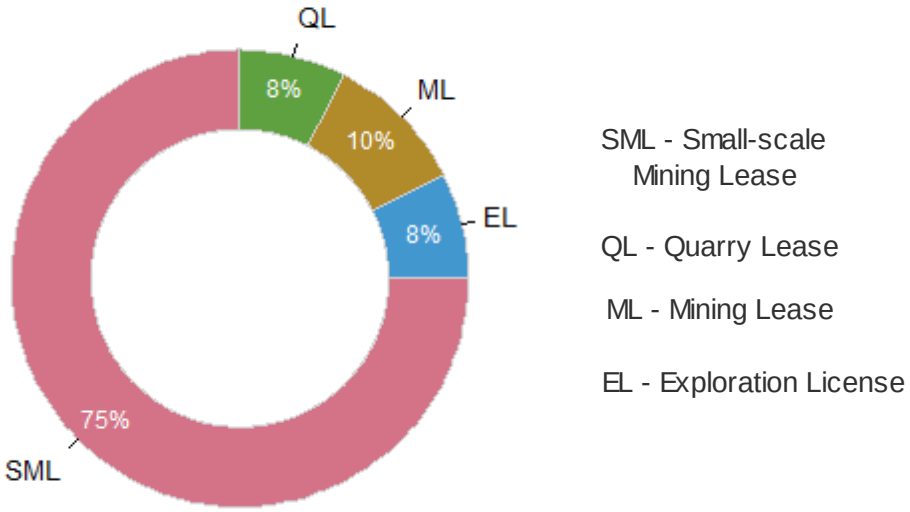

Figure 5.9 Respondents license types

(b) Years in operation

BOI only finances brownfield mining operations, which means the mining operation must have been in existence at least for a while before seeking loans. BOI uses this to verify that the operation is viable at least to have kept running in the short term. For this study, we are adopting a minimum period of above 1 year, for the mining operation to be considered eligible for BOI loans. The result shown in Figure 5.6 in section 5.1.1 reveals that only 4% of the miners have worked for less than 1 year in their mine site. Thus, 96% of the miners are said to have been running their mine site for more than 1 year and are eligible for the BOI loan considering their years in operation.

(c) Membership of the cooperative society

The BOI does not provide loans to individual miners, instead miners are required to join a mining cooperative society. This cooperative society is then required to register with the Nigeria ministry of mines and steel development, which will then coordinate their loan application to the BOI. This provides a form of social security cover for the loan application. In case of default in loan repayment by the miner, the president of the cooperative would be held responsible. Figure 5.10 shows miners' responses to whether or not they are members of a mining cooperative society. The chart shows that only 15% of the miners are members of mining cooperative societies such as miners who are into gold and gemstones mining. Thus, only 15% of the miners are eligible for the BOI loan under this condition.

Figure 5.10 Membership of mining cooperative society

(d) Ability to afford loan interest rate

The BOI requires that miners pay a minimum of 5% as interest on the loan provided to ASM operations. To estimate the proportion of the miners who could afford this interest rate,

miners were asked to state the interest rate they could afford to pay based on their current level of productivity. Figure 5.11 shows the result of this assessment. The chart shows that only 36% of the miners could afford to conveniently pay up to 5% on a loan sum as interest-based on their current level of productivity.

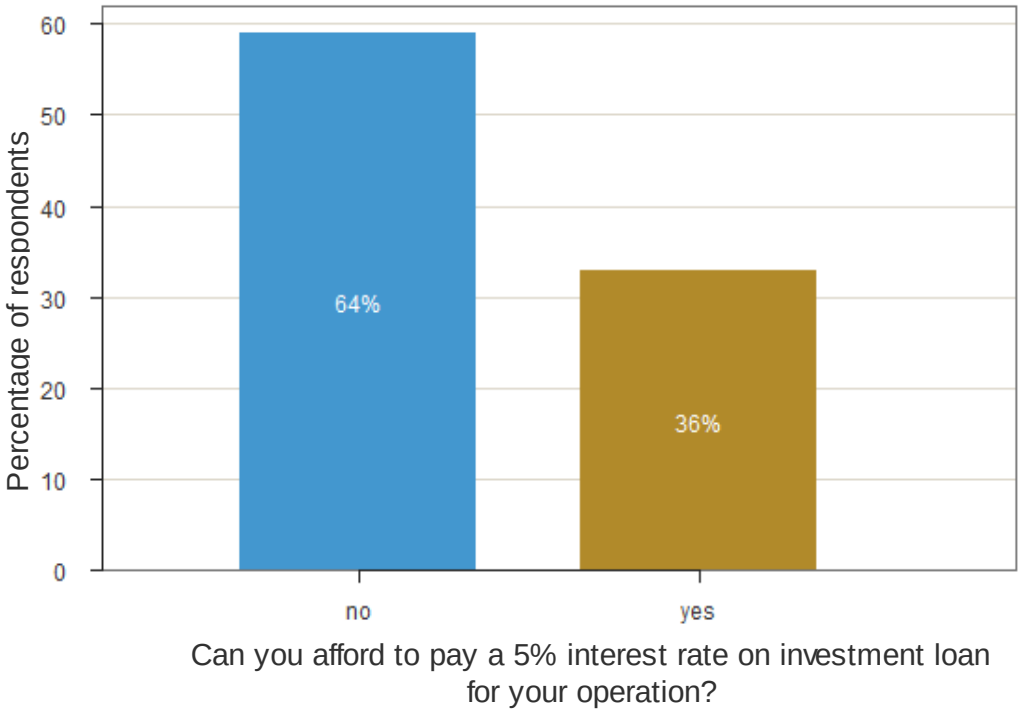

Figure 5.11 Respondents that can afford loan interest rate

(d) Availability of Guarantors

The interview sessions with the BOI revealed that the bank does not require any form of Collateral from ASM operators before giving them a loan. Instead, they require that the borrower provides a competent Guarantor who will stand as surety for the miner to provide a form of collateral security to the bank. The profile of the prospective Guarantor required by the bank was provided to the Researcher and this is inputted in the data collection

instrument for the respondent to indicate if they can fulfil the Guarantor requirement of the BOI or not. According to the BOI, prospective Guarantors may include any of the following: an employee of a blue-chip company in Nigeria (such as oil companies, banks, etc.), a political office holder, a royal father, or a senior civil servant. The result of this survey is shown in Figure 5.12. The result shows that 64% of the miners only have their family members to stand for them, who are not eligible to stand as Guarantors, and 4% of the miners do not have any form of Guarantors, making a total of 68% of the respondents without prospective Guarantors. This indicates that only 32% of the respondent can comply with the condition of availability of Guarantors for access to BOI loans.

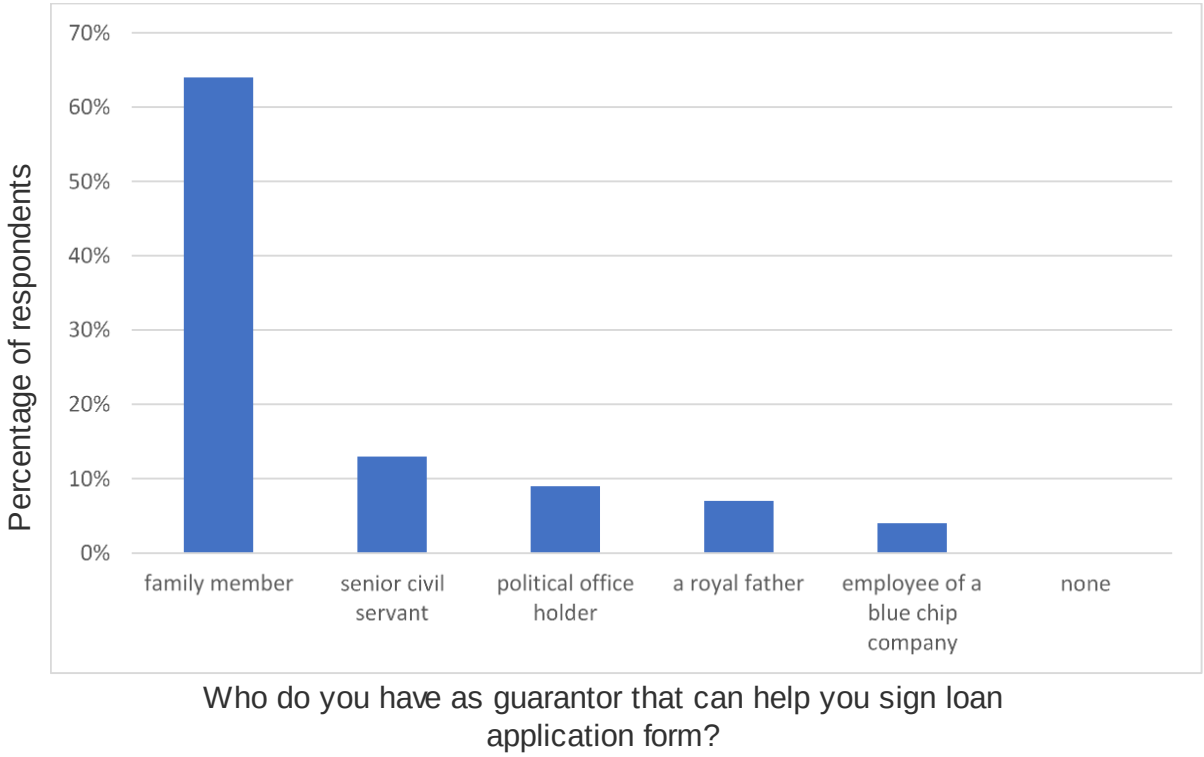

Figure 5.12 Available guarantors for loan application forms

5.1.3 Reserve estimation in ASM

It is a standard requirement in formal lending for recipients of mining loans to have proof of availability of ore reserve. The literature has shown that the reason for the formal lender's lack of interest in ASM is the lack of proof of adequacy of ore reserve for the mining operation. This section, therefore, involves an assessment of the ASM operator's knowledge in ore reserve estimation and the need to have minimum ore reserve before mining commences.

(a) Knowledge in ore reserve estimation

The miners were asked if they know ore reserve estimation. Figure 5.13 shows the result of this assessment. The chart shows that 73% of the respondents do not have any form of knowledge about ore reserve estimation and only 27% of the respondent have some level of knowledge in ore reserve estimation. Figure 5.14 shows that out of the 27% who know about ore reservation, 40% learned about it in school (those were the miners who studied mining in school), 52% learned from field experience and only 8% learned from organised workshops and seminars.

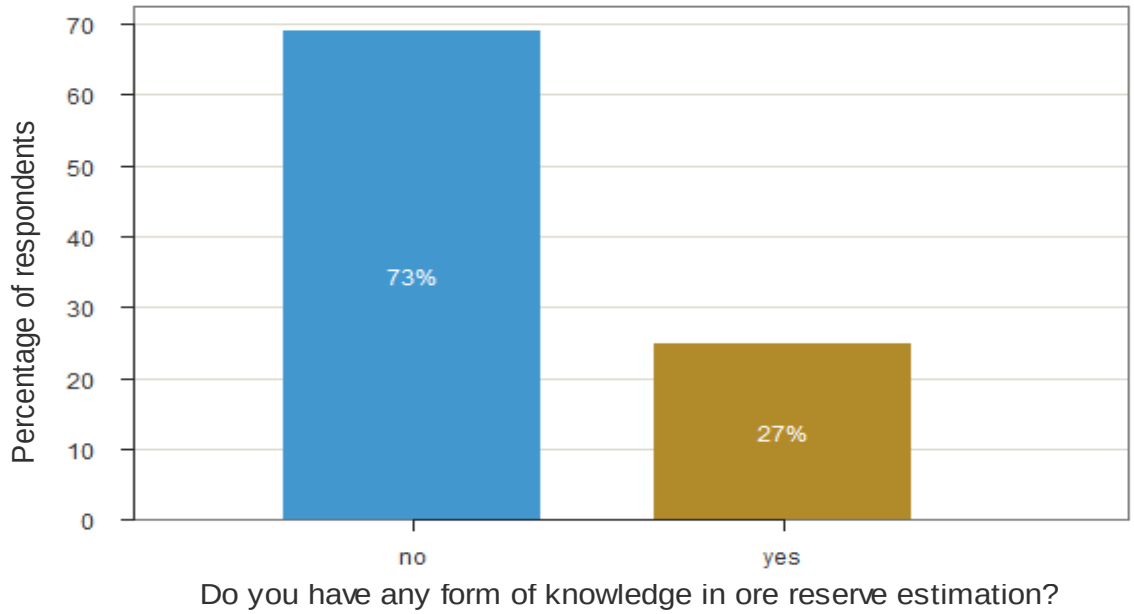

Figure 5.13 Respondents of knowledge in ore reserve estimation

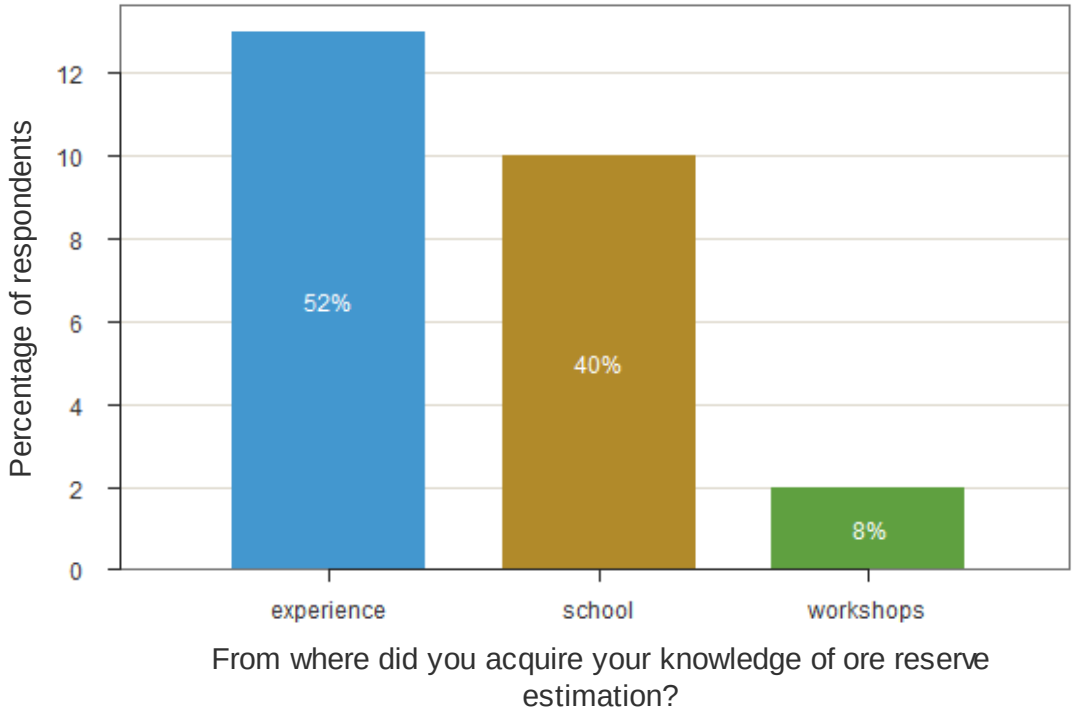

Figure 5.14 Respondents source of knowledge in ore reserve estimation

(b) Knowledge on the certainty of reserve

An assessment was carried out on those who do not know ore reserve estimation to assess how they ascertain their ore reserve before investing their time and resources on the deposit. From the result shown in Figure 5.15, 14% of the miners stated that they only search for the minerals they are interested in and once they find traces, they start mining. Another 67% of the miners stated that they moved into their current mine site after the former owners of the site vacated it. Thus, they assumed that there is no need for any form of reserve estimation since they are aware of the potential of the mineral deposit. The remaining 19% stated that they are ascertaining the potential of the deposit through their instinct which is based on their years of experience in the ASM occupation.

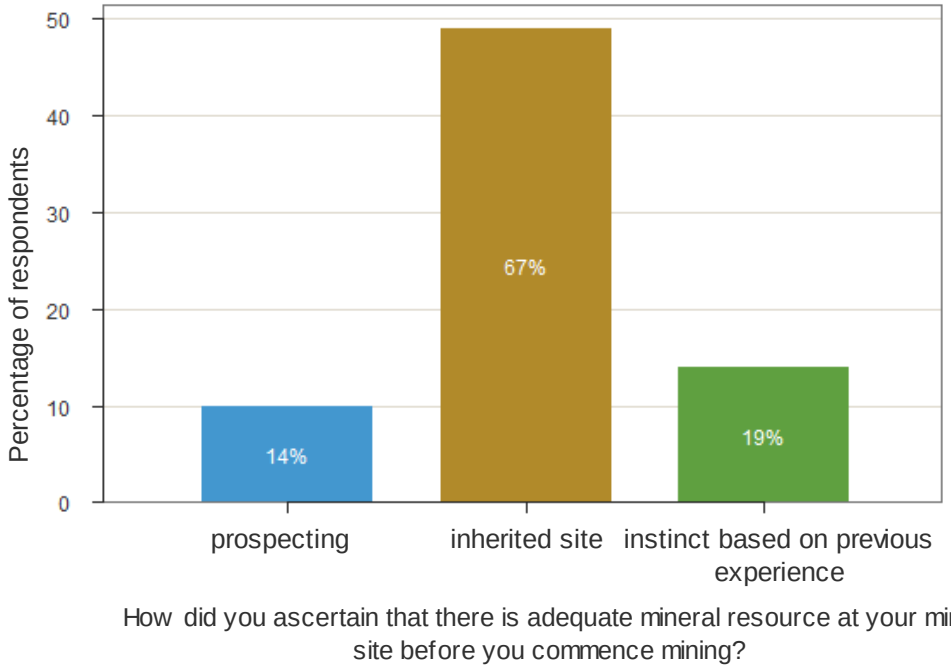

Figure 5.15 How respondents operate without reserve estimation

5.2 Inferential statistics

As its name implies, inferential statistics use a sample of data selected from a study population to describe and make inferences about the population. It is different from descriptive statistics in the sense that while descriptive statistics only describe and summarize a data sample, inferential statistics aims to use the data sample to study and learn about the population that the sample represents. The inferential statistics carried out in this study involve the use of logistic regression to develop models that predict the creditworthiness of an ASM operation using identified credit risk variables. As discussed in chapter two of this study, the adoption of logistic regression follows the use of logit scoring models to predict credit default risks of SMEs in Behr and Güttler (2007) and a more recent study of Kanapickiene and Spicas (2019).

5.2.1 Predicting creditworthiness from minimum reserve

To develop a model that uses knowledge of minimum reserve in a deposit to predict creditworthiness, the data set used comprises of data from the 96 ASM respondents collected, The two variables of interest in the model are miners' knowledge of existing ore reserve estimates and miners' access to formal lending . The percentage of respondents who have accessed formal loans is relatively small. Thus, to ensure that the model is not skewed, some samples were removed to ensure a balanced proportion of the dependent and the independent variable. The dataset is then randomized so that samples were selected from the dataset through random sampling. The randomized sample is then used to develop the model.

The results of the simple logistic regression are shown in Table 5.1 and Table 5.2.

Table 5.1. Deviance Residuals

Min	1Q	Median	3Q	Max
-1.7214	-0.66802	0.02502	0.71809	1.79412

Table 5.2. Coefficients

	Estimate	Std. Error z value		Pr(>|z|)
(Intercept)	-1.3863	0.5590	-2.480	0.013143 *
KnwResEstyes	2.6101	0.7559	3.453	0.000554 ***

Using the coefficients, the result of the logistic regression shown above correspond to the following model:

$$\text{formal fund} = -1.3863 + 2.6101 \times \textit{yes to ore reserve estimate} \quad (5.1)$$

The variable for 'knowledge of ore reserve estimate' is 1 when the miner knows his mine site's ore reserve estimate, and 0 when the miner does not know his mine site's ore reserve. From equation (5.1), if a miner does not know his mine site's reserve estimate, then the probability of his access to formal funding is given by:

$$formal\ fund = -1.3863 + 2.6101 \times 0 \quad (5.2)$$

$$formal\ fund = -1.3863 \quad (5.3)$$

Since R develop a model for logistic regression in log(odds), then the log(odds) that a miner without knowledge of his mine site's ore reserve will access formal funding is -1.3863.

Similarly, if a miner knows his mine site's ore reserve estimate, then access to formal funds is given by:

$$formal\ fund = -1.3863 + 2.6101 \times 1 \quad (5.4)$$

$$formal\ fund = -1.3863 + 2.6101 \quad (5.5)$$

Since the first term on the right-hand side of equation (5,5) is the log(odds) of a miner without knowledge of ore reserve accessing the formal fund, then 2.6101 represents an increase in the log(odds) for a miner with knowledge of his mine site's ore reserve to access formal funding.

A plot of the probability of access to formal funds against those who obtained formal funding is shown in Figure 5.16. The plot shows that most of the miners with the formal fund (the ones in turquoise, coded as 1) are predicted to have a high probability of having access to

formal funding. Also, the plot reveals that most of the miners without formal funds (the ones in salmon, coded as 0) are predicted to have a low probability of having access to formal funding. The graph, therefore, proves the level of accuracy of the logistic regression model.

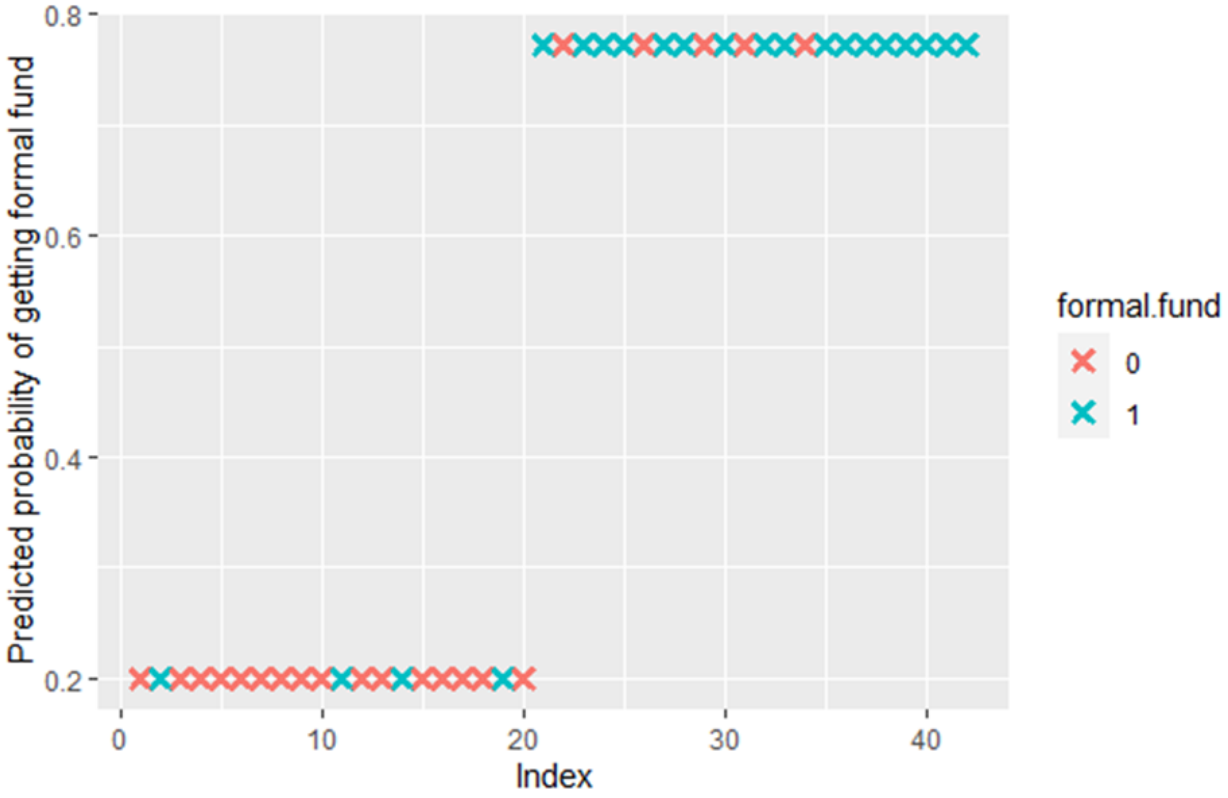

Figure 5.16 Predicted probability of obtaining formal fund for ore reserve variable

5.2.2 Predicting creditworthiness from license status

A model was developed to examine the effect of the license status of a miner on the creditworthiness of an ASM operator. To develop this model which uses the license status of the ASM operations to predict its creditworthiness, the sampled dataset of the 96 respondents is cleaned, and randomized as discussed in section 5.2.1. The result of the logistic regression model development in R is shown in Tables 5.3 and 5.4.

Table 5.3. Deviance Residuals

Min	1Q	Median	3Q	Max
-1.3018	-1.3018	0.2513	1.9728	1.9728

Table 5.4. Coefficients

	Estimate	Std. Error z value		Pr(>|z|)
(Intercept)	-1.792	1.080	-1.659	0.0971
Val.licyes	2.079	1.133	1.836	0.0664

It can be seen in Table 5.4 (fourth column) that the p-value of this regression model is 0.0664, which is higher than the confidence level of 0.05. For a model to be statistically significant, it is required that there is a 95% chance that the independent variable (valid license status) successfully predicts the dependent variable (formal fund). For this condition to be met, the p-value for the model must be lower than 0.05. Thus, this condition cannot be achieved in this model since the p-value is 0.0664. It can therefore be inferred that the regression model is not statistically significant. However, since the difference of the p-value from the confidence level is relatively little (1.6%), the simple logistic regression model may still be accepted.

5.2.3 Predicting creditworthiness from the availability of loan guaranty

A model is developed that predicts creditworthiness from the availability of a guarantor for the loan. To develop this model, the sampled dataset of the 96 respondents is cleaned, and randomized as discussed in section 5.2.1. The result of the logistic regression model development is shown in Table 5.5 and Table 5.6.

Table 5.5. Deviance Residuals

Min	1Q	Median	3Q	Max
-1.4823	-0.6681	0.1162	0.9005	1.7941

Table 5.6. Coefficients

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.3863	0.6455	-2.148	0.03174 *
Hav,guayes	2.079	1.133	1.836	0.00648 **

It can be observed from Table 5.5 (fourth column) that the p-value for the model is 0.00648 which is lower than the confidence level of 0.05, indicating that the model is statistically significant and as such, the availability of a loan guarantor is a good predictor of access to the formal fund.

Using the new data frame for formal funding and availability of guarantors, a plot of the probability of access to formal funds along with their actual funding status is shown in Figure 5.17. The plot shows that most of the miners with the formal fund (the ones in turquoise, coded as 1) are predicted to have a high probability of having access to formal funding. Also, the plot reveals that most of the miners without formal funds (the ones in salmon,

coded as 0) are predicted to have a low probability of having access to formal funding. The graph, therefore, proves the level of accuracy of the logistic regression model.

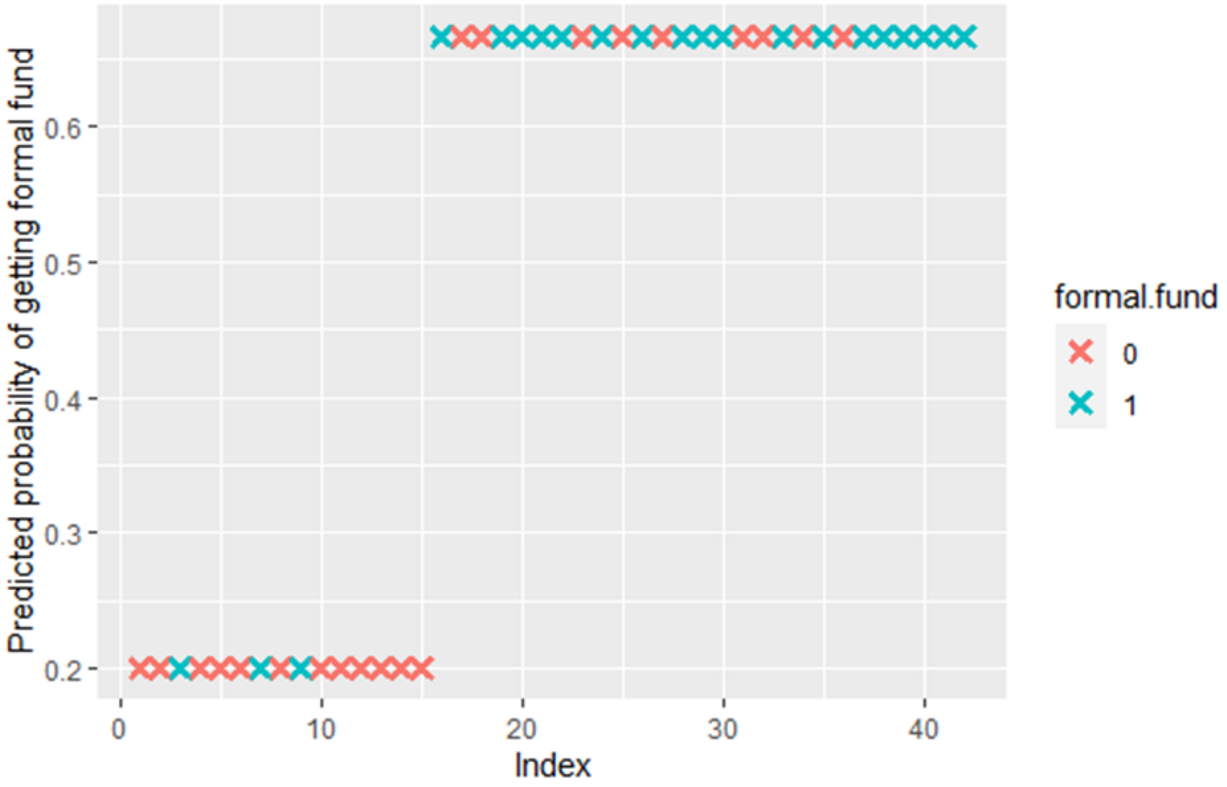

Figure 5.17 Predicted probability of obtaining formal fund for the availability of guarantor variable

5.2.4 Predicting creditworthiness from the ability to afford interest rate

A model is developed that predicts creditworthiness from the ability of the miner to afford loan interest rates. A blanket interest rate of 5% is used for the study based on the requirement of the formal lender adopted for this study, the BOI. Miners who could afford to pay up to a 5% interest rate were coded as “yes” while miners who could not afford up to that rate were coded as “no” for this model. To develop the model, the sampled dataset of

the 96 respondents is cleaned, and randomized as discussed in section 5.2.1. The result of the logistic regression model development is shown in Table 5.7 and Table 5.8.

Table 5.7. Deviance Residuals

Min	1Q	Median	3Q	Max
-1.42944	-0.83463	0.05506	0.94476	1.56447

Table 5.8. Coefficients

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.8755	0.5323	-1.961	0.0499 *
FeasReptAvailyes	1.4508	0.6760	2.146	0.0319 *

It can be observed from Table 5.8 (fourth column) that the p-value for the model is 0.0319 which is lower than the confidence level of 0.05, indicating that the model is statistically significant and as such, having the ability of a miner to afford interest rate is a good predictor of access to the formal fund.

Using the new data frame for formal funding and ability to afford interest rate, a plot of the probability of access to formal funds along with their actual funding status is shown in Figure 5.17. The plot shows that most of the miners with the formal fund (the ones in turquoise, coded as 1) are predicted to have a high probability of having access to formal funding. Also, the plot reveals that most of the miners without formal funds (the ones in salmon, coded as 0) are predicted to have a low probability of having access to formal funding. The graph, therefore, proves the level of accuracy of the logistic regression model.

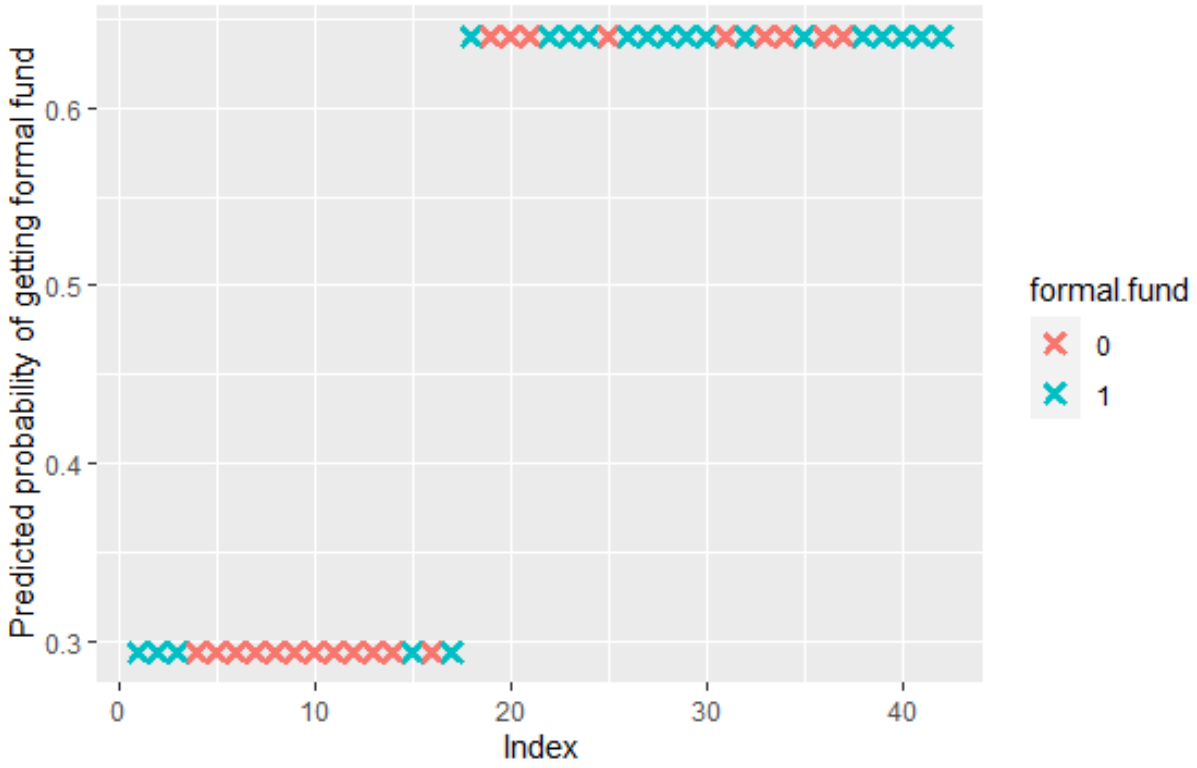

Figure 5.18 Predicted probability of obtaining formal fund for the ability to afford interest rate variable

5.2.5 Predicting creditworthiness from membership of the cooperative society

A model is developed that predicts access to formal funding using the membership of the ASM operator in a mining cooperative society. To develop this model, the sampled dataset of the 96 respondents is cleaned, and randomized as discussed in section 5.2.1. The result of the logistic regression model development is shown in Table 5.9 and Table 5.10.

Table 5.9. Deviance Residuals

Min	1Q	Median	3Q	Max
-1.79412	-0.71809	-0.02502	0.66805	1.72140

Table 5.10. Coefficients

	Estimate	Std. Error z value	Pr(>|z|)

(Intercept)	-1.2238	0.5087	-2.405	0.016152 *
Min.coopyes	2.6101	0.7559	3.453	0.000554 ***

It can be observed from Table 5.10 (fourth column) that the p-value for the model is 0.000554 which is lower than the confidence level of 0.05, indicating that the model is statistically significant and as such, membership of the cooperative society is a good predictor of access to the formal fund.

Using the new data frame for formal funding and miners' membership of mining cooperative society, a plot of the probability of access to formal funds along with their actual funding status is shown in Figure 5.19. The plot shows that most of the miners with the formal fund (the ones in turquoise, coded as 1) are predicted to have a high probability of having access to formal funding. Also, the plot reveals that most of the miners without formal funds (the ones in salmon, coded as 0) are predicted to have a low probability of having access to formal funding. The graph, therefore, proves the level of accuracy of the logistic regression model.

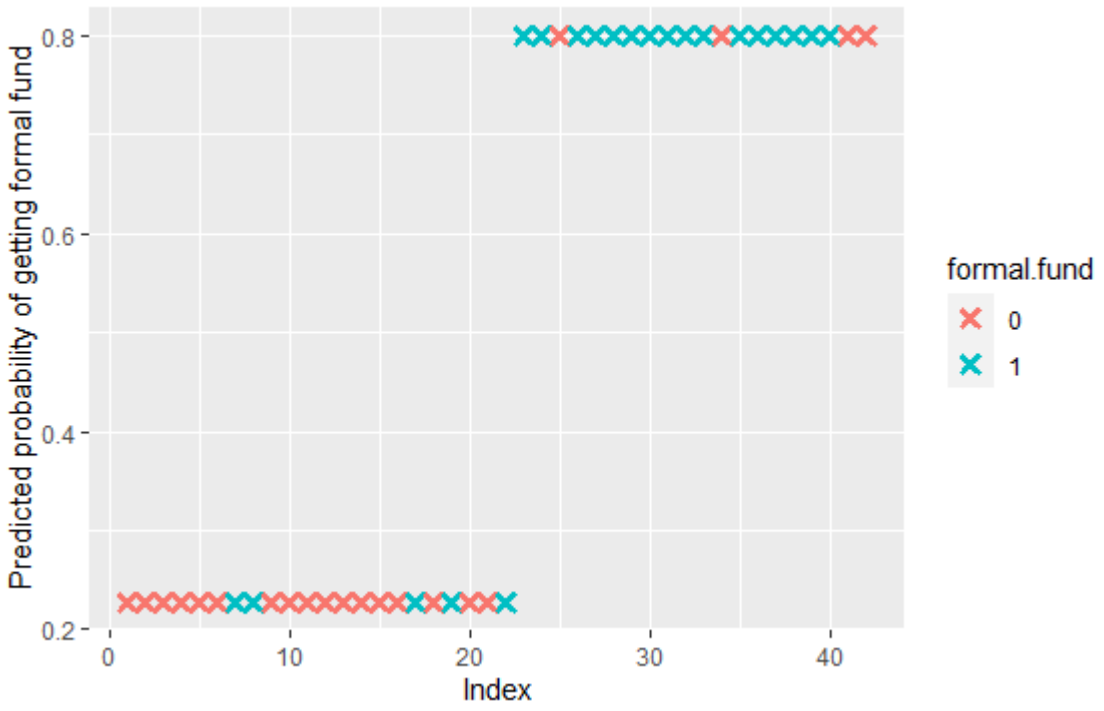

Figure 5.19. Predicted probability of obtaining formal funds using the membership of cooperative society variable

5.2.5 Multiple logistic regression

To develop a model that involves the prediction of access to formal funds using all the identified variables required by formal lenders, a multiple logistic regression analysis is required. Multiple logistic regression applies when there is a single dichotomous outcome and more than one independent variable. Whereas simple logistic regression analysis refers to the regression application with one dichotomous outcome and one independent variable.

In this multiple regression, all the identified variables from formal lenders were regressed with the formal fund to determine the effect of the identified variables on formal funding. The variables include the availability of reserve estimate, ability to pay an interest rate, ability to provide a guarantor, availability of feasibility report, membership of mining cooperative society, and ability to meet criteria for the expected duration of the operation.

Upon development of the simple logic regression models from section 5.2.1 to 5.2.5, it is observed that only availability of reserve estimate, ability to provide a guarantor, ability to pay the interest rate and membership of mining cooperative society have statistically significant models when regressed with formal lending. Thus, a model is developed that predicts formal funding using the four identified statistically significant variables. This multiple regression model shown in Table 5.11 and Table 5.12 provides the probability of obtaining access to formal funding using the identified credit risk variables in ASM.

Table 5.11. Deviance Residuals

Min	1Q	Median	3Q	Max
-2.19371	-0.41226	0.04141	0.43471	2.23945

Table 5.12. Coefficients

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.413	1.416	-3.118	0.00182 **
KnwResEstyes	2.003	1.030	1.945	0.05182 .
hav.guayes	1.991	1.020	1.951	0.05102 .
afford.intyes	1.238	1.123	1.102	0.27041
min.coopyes	2.732	1.046	2.611	0.00904 **

To determine the overall effect size of all the independent variables on access to the formal fund, the "Pseudo R-squared" and its p-value are calculated in R. To calculate McFadden's Pseudo R^2, we pull the log-likelihood of the null model out of the logistic variable by getting the value for the null deviance divided by -2 as shown below:

$$\text{ll.null} < -\text{logistic\$null.deviance}/-2 \quad (5.6)$$

Then we pull the log-likelihood of the overall model out of the logistic variable by getting the value for the residual deviance and dividing by -2 as shown below:

$$\mathrm{ll.proposed} < -\mathrm{logistic\$deviance}/-2 \quad (5.6)$$

Then McFadden's Pseudo R^2 is computed as follows:

$$\mathrm{ll.null} - \mathrm{ll.proposed} \,/\, \mathrm{ll.null} \quad (5.7)$$

which gives the following result:

$$0.5255773 \quad (5.8)$$

This is the overall effect size of this multiple logistic regression model

To compute the p-value for the R-squared, the same log-likelihoods are used using a Chi-square distribution which is computed in R as follows:

$$1 - \mathrm{pchisq}(2 * (\mathrm{ll.proposed} - \mathrm{ll.null}), \mathrm{df} = (\mathrm{length}(\mathrm{logistic\$coefficients}) - 1)) \quad (5.9)$$

Which gives the following result:

$$3.691443\mathrm{e} - 06 \quad (5.10)$$

The p-value shown above is quite small (smaller than 0.05), which implies that the R-squared value for the model is not due to luck, that is, the R-Squared value is considered statistically significant in proving the effect of the independent variables on the dependent variable (access to formal fund).

Using the new data frame for formal funding and the four independent variables shown in Table 5.12, a table for the predicted probability of obtaining access to formal funds is

generated. The predicted probability of access to formal funds is then plotted along with the actual funding status of ASM operators. The result is shown in Figure 5.20. The plot shows that most of the miners with the formal fund (the ones in turquoise, coded as 1) are predicted to have a high probability of having access to formal funding. Also, the plot reveals that most of the miners without formal funds (the ones in salmon, coded as 0) are predicted to have a low probability of having access to formal funding. The plot, therefore, proves the level of accuracy of the logistic regression model.

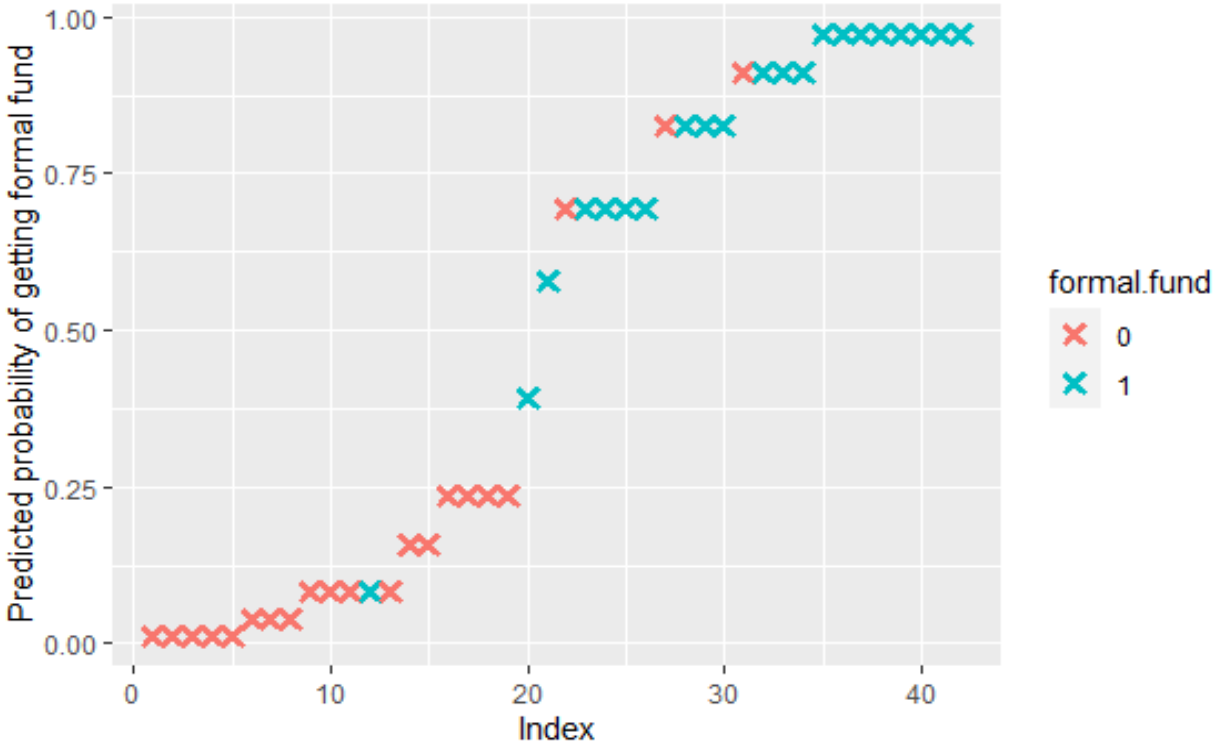

Figure 5.20 Predicted probability of access to formal fund along with the actual funding status of ASM operators

5.2.6 Limitations of the models

To develop an unbiased model, the proportion of miners who have accessed formal loans needs to be equal to those who have not accessed the loan. Since only a little proportion of ASM operators have accessed formal loans, then only a small portion of the data collected

from the field is useful for the model development. Therefore, the limited availability of formal lending in the ASM industry reduces the efficiency of training of the prediction model. Still, the model developed provides a template and a mechanism for computation and comparison of creditworthiness of ASM operations by capturing the credit risk variables.

As more ASM operators access formal lending due to improved formalisation efforts in the ASM industry, more data would be available to train the predictive model on creditworthiness in ASM in future studies. This study, therefore, provides a benchmark for future research in the area of credit risk prediction for a viable ASM industry.

5.3 Conclusion

This chapter presents the results of the quantitative research undertaken in this study, which was carried out on a sample of 100 ASM operators. The purpose of the quantitative study was to develop models that predict the credit risk behaviour of ASM operations. For this purpose, descriptive and inferential statistics were carried out.

In this chapter, two of the research questions for the study were answered. Firstly, a model was developed using the miner's knowledge of the ore reserve estimate of his mineral deposit to predict (in log odds) his probability of attracting formal funds. Also, a model was developed using all the statistically significant credit risk variables in the study to predict (in log odds) the probability of an ASM operator to attract formal funds. To prove the accuracy of the credit-risk logit model, a graph was plotted which shows the predicted probability of access to formal funds along with the actual funding status of ASM operators. A summary of the simple logistic regression models showing the relationship between the dependent variable and various independent variables is shown in Table 5.13.

Table 5.13. Model summary

Independent variables	Model in log (odds)
Ore reserve estimate	Formal fund = -1.3863 + 2.6101 x yes to ore reserve estimate
Valid license	Formal fund = -1.792 + 2.079 x yes to valid license
Availability of guarantor	Formal fund = -1.3863 + 2.079 x yes to guarantor
Ability to afford interest rate	Formal fund = -0.8755 + 1.4508 x yes to interest rate
Membership of cooperative	Formal fund = -1.2238 + 2.6101 x yes to member of cooperative

CHAPTER 6 CONCLUSION

Artisanal and small-scale mining operations (ASM) have suffered from a lack of formal lending owing to formal lenders' perception of the financially risky nature of the operations. The situation is further compounded by the unavailability of a documented mechanism for estimating the credit risks of ASM operations. This necessitates the need to develop models, specifically for the estimation of the expected risks of lending to ASM operations. The estimation should be based on the factors that qualify as risk criteria in a "not so formal" industry such as ASM. This will help the operators of ASM activities to identify the level of the credit worthiness of their operations. It will also help lenders to identify and adequately price the risk of lending to ASM operations.

Enhancing credit worthiness requires optimization of credit risk variables. There are several variables that lenders consider before lending to mining operations. For ASM, a review of the literature identifies some perceived credit-risks that leads to the apathy of formal lenders in the industry, and they included assurance of availability of the mineral resource, availability of collateral security for the loan sum, availability of social security for the borrower, ability to pay an interest rate based on level of productivity, miners' technical and financial management competence and the proof of the existence of the mining operation to be funded.

This research examines the concept of credit risks in ASM in the study area intending to develop models that predict the risk of lending to ASM operations using identified credit risk variables. To achieve this, a study was conducted in the financial institution to understand the key variables they would look out for in minimizing their risks of lending to ASM operations. Furthermore, a study was conducted on a group of ASM stakeholders which comprises heads of ASM cooperative societies, union, and association heads, to examine their perspectives on the inherent credit risks or ASM operation.

Once the credit risk variables were identified, a research questionnaire was developed based on the identified credit-risk criteria, and copies were distributed to a sample of 100 ASM operators to examine their eligibility to access formal funds. A total of 96 copies of the research questionnaire were returned. The result of the quantitative analysis involving descriptive and inferential statistics was presented. Findings on research questions raised to guide the study, the contribution of the study to the body of knowledge as well as suggestions for further investigation to improve the viability of ASM operations by optimising its credit risks, are all provided in this conclusive part of the study.

6.1 Findings concerning the research questions

The primary research question stated in chapter 1, which this thesis seeks to answer is *How can the creditworthiness of an existing ASM operation be evaluated, relative to the credit risk variables inherent in a typical ASM operation?*

To answer the primary research question, secondary questions were developed, and they are reviewed here. The findings from each research question are also discussed.

> *What methods do financial institutions adopt in assessing the credit risks of ASM operations in the study area?*

Financial institutions were visited to understand their methods of assessing the credit risks of ASM operations. Three commercial banks were visited in the study area for interviews. However, the banks stated that they do not offer loans to ASM operations because they do not have the risk tolerance for such activities. Consequently, the Nigeria Bank of Industry (BOI), a development finance institution that offers loans to small and medium scale enterprises in Nigeria, was contacted. Upon successful completion of interviews with managers of the solid mineral unit of the bank, it was observed that the model used by the

bank for estimating credit worthiness for medium-scale mining companies is quite different from those of ASM operations.

To successfully access a BOI loan, the following criteria must be met by an ASM operator: the mining business must be registered; there must be a valid license for the operation or a signed permission letter from a license owner granting the ASM operator access to mine in his/her concession area; there must be an available mine site for the ASM operator to operate from; a guarantor must be available who will meet conditions identified in chapter 4 of this thesis; a geophysical survey report detailing the extent of the mineral resource must be available; the operator must be able to pay the mandatory 5% interest rate on the principal sum; the operator must be a member of a registered mining cooperative society, and the mining operation must be a brownfield, that is, must already be in operation for a while before submission of the loan request. The information gathered from the bank provides background knowledge on the requirements for ASM loan applications in a financial institution.

> *What is the level of the practical use of a minimum reserve to evaluate the risk of ASM investment in the study area?*

The investigation carried out at the BOI revealed that to confirm the availability of the minimum mineral reserve for the mining operation, the bank liaises with the Ministry of Mines and Steel Development (MMSD) to verify the authenticity of the presented mineral title. Then the bank reviews the geophysical survey report presented to establish the sufficiency of the reserve. The bank also visits the mine site to confirm the availability of the mineral resources on the ground and to ensure that the mining operation to be financed is already in existence. This visitation is carried out by the bank's project officer.

The bank does not have a unit that is technically equipped to examine the sufficiency of reserve based on the documentation submitted by the prospective lender. However, to estimate the minimum reserve for the operation that will guarantee that there is enough deposit on the ground to repay the loan sum, the BOI engages the service of consultants who are competent in ore reserve estimation. The bank then ensures the credit coverage, and the repayment period does not exceed the estimated life span of the mine.

What model can be developed, using the minimum reserve, to predict the credit risk behaviour of an ASM operation?

A simple logistic regression model is developed that provides the log (odds) of the probability of access to formal loans using the miner's knowledge of his ore reserve estimate. The use of logit models to predict credit risks is modelled after the study of Kanapickiene and Spicas (2019) who modelled the risk of lending to small-scale companies in Lithuania using non-financial variables. More details on the logit models can be found in Chapter 5 of this thesis.

What model can be developed to predict the creditworthiness of an ASM operation using the credit risk variables?

A multiple regression model was developed to predict the credit worthiness of an ASM operation using the identified credit risk variables. In this multiple regression, all the identified variables from formal lenders were regressed with the formal fund to determine the effect of the identified variables on formal funding. The variables include the availability of reserve estimate, ability to pay an interest rate, ability to provide a guarantor, availability of feasibility report, membership of mining cooperative society, and ability to meet criteria for the expected duration of the operation.

Upon development of the simple logic regression models to predict the effect of each of the study variables on access to the formal fund, it is observed that only availability of reserve estimate, ability to provide a guarantor, ability to pay the interest rate and membership of mining cooperative society have statistically significant models when regressed with formal lending. Thus, a multiple regression model is developed that predicts formal funding using the four identified statistically significant variables. The effect size of the model was also computed along with its p-value which can be seen in Chapter 4 of this thesis.

6.2 Research contribution

The research contributes the following to scientific knowledge:

- It adds credence to the argument of proponents of ASM formalisation by providing a mechanism through which the viability of the operation can be assessed for funding intervention.
- It presents an avenue for estimating the risk of lending to an ASM operation using identified credit risk variables. Thus, it provides a new perspective for the prediction of the viability of an ASM operation.
- Formal lenders such as commercial or microfinance banks can use the logit models to evaluate the credit worthiness of a loan applicant in ASM
- Management of ASM firms can use the logit models to self-examine their eligibility for formal loans
- The R codes generated can be used for further studies to model the probability of access to formal funds within or outside the ASM industry.

6.3 Suggestions for further research

The study was developed for predicting credit risks of ASM operation using non-financial variables such as knowledge of ore reserve estimate, availability of collateral security,

availability of social collateral, availability of mineral title among others. Credit risks can be estimated using financial and non-financial variables. An estimation of credit risks in ASM using financial variables is also essential to provide a guideline to be used by institutions such as banks. Similar models developed in previous studies that can guide future research in ASM which used financial/accounting-based variables in SMEs can be found in Altman and Sabato (2007) and Lin and Ansell (2015).

The risk elements used in developing the models in the study are variables that can be controlled by the ASM operator. However, the literature suggests there are factors outside the control of the miner, such as market conditions, political factors, and environmental conditions, which can all affect the credit risks of an ASM operation as well (see, Benning, 2000). These are areas that future studies can consider in building credit risk models for ASM operations.

One variable identified in the literature as a risk factor that is of concern to formal lenders is the technical and financial competence of ASM operators. This study did not focus on skills shortage, training and/or capacity building because, the Nigerian Mineral and Mining Act of (2007) considers capacity building as one of the responsibilities of the Nigerian government to formalise the industry (Adefulu, 2010). As such, it is not a parameter that is completely under the control of ASM operators; which are the variables that this study focuses on. Also, the model developed in this study for creditworthiness is based on the requirements/parameters for a creditworthy application which were provided by the government-owned bank- BOI, and variables that were not part of BOI criteria were not included in the model formulation. There are studies such as Perks (2016), that dispel the perceived risk of t lack of technical competence ASM operators as an excuse for their non-financial inclusiveness. Perks (2016) argues that in Rwanda and Tanzania, many ASM operators are retrenched employees of large-scale mining companies, and they have

learned the use of modern mining equipment in these companies, but are still left out of formal lending services. For the financial capability of miners, the study argues that t an accountant can be hired by the mining cooperative society, under which ASM operations are registered, who will formalise the financial dealings of each ASM operation. This is expected to cover the financial risks of ASM operations. Still, further research can be carried out on how to incorporate technical and financial competence in ASM credit risk models.

6.4 Recommendations

The path towards upgrading ASM operations to a more sustainable form of mining practice should involve an effort towards improving the ability of the operations to attract formal funding. However, recipients of loans must be credit-worthy companies with financially viable operations. It is therefore recommended that future study direction should consider modifying, scaling, and improving available models for proving the viability of ASM operations. In this direction, considering the nature of ASM, such models must be developed differently from the methodology for proving the viability of large-scale mining operations which usually take several years to construct.

It is equally important that the scope of the current formalisation efforts of ASM is expanded to incorporate the exposition of ASM operators to the credit risks inherent in their operation and training operators on mechanisms with which such risks can be reduced. Also, for the effective formalisation of ASM, one key initiative that may play a sustainable role in enhancing ASM operators' access to credit is the strengthening of associative entrepreneurship movements such as miners' cooperatives. First, this form of association would help miners to accumulate enough capital with which they could engage in more viable and safer operations (Saldarriaga-Isaza, Villegas-Palacio, and Arango, 2013). Additionally, due to the perceived itinerant nature of artisanal mining, such associations

provide a face for artisanal miners, a governing structure, and an avenue through which miners could be held accountable for excesses in their operations.

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APPENDICES

APPENDIX A

Research Questionnaire for Group 1 (ASM operators)

Research Questionnaire

Informed consent form

(Form for research participant's permission)

1. Project information

1.1 Title of the research project: Credit-risk prediction for a viable artisanal and small-scale mining (ASM) operation

1.2 Researcher details: Eniowo Olushola Daniel, Mining Engineering Department, Room 5-50, Mineral sciences building, University of Pretoria, South Africa. E-mail address: od.eniowo@up.ac.za. Phone: +2347067802666.

1.3 Research study description. The objectives of the study are to evaluate the methods that financial institutions adopt in assessing the credit risks of artisanal and small-scale mining operations in the study area; examine through survey, the level of the practical use of a minimum reserve to evaluate the risk of ASM investment in the study area; predict that an ASM operation is credit-worthy by evaluating the credit risk variables in the real-life case study, and develop a model to predict risks behaviour of ASM through detailed analysis and computer simulation.
To achieve the above objectives, the respondent is required to fill out a well-structured questionnaire or respond to unstructured interview questions.
There are no known risks involved in participating in this study since the response provided by respondents are for research purposes alone.

2. Informed consent

2.1 I, _____hereby voluntarily grant my permission for participation in the project as explained to me by the Investigator, Eniowo Olushola Daniel.

2.2 The nature, objective, possible safety, and health implications have been explained to me and I understand them.

2.3 If there is an interview session, I permit the investigator to have an audio recording of the interview session for further analysis of data

2.3 I understand my right to choose whether to participate in the project and that the information furnished will be handled confidentially. I am aware that the results of the investigation may be used for publication.

2.4 Upon signature of this form, the participant will be provided with a copy.

Signed: _____ Date: _____

Witness: _____ Date: _____

Researcher: _____ Date: _____

Research Questionnaire

Research Title: Credit Risk Prediction for Artisanal Mining Operation

Instructions: Please tick (√) or fill in as appropriate.

Section A: **Occupation**

(i) Is Artisanal and Small-Scale Mining (ASM) your primary occupation?

Yes	No

(ii) Do you have another occupation, apart from Artisanal and Small-scale Mining (ASM)?

Yes	No

(iii) If you selected "Yes" to question (ii), please indicate your secondary occupation

Farming	Civil Service	Public Service	Business owner	An employee in a private Establishment	Artisan (Carpenter, Welder, etc.)	Others (pls. specify)

Section B: Operation

(i) How long have you been in this operation?

Less than 1 year	1 – 2 years	3 – 5 years	5 – 10 years	Above 10 years

(ii) What mining phase do you specialise in? (You may tick as many boxes as possible)

The whole mining cycle	Excavation (Mineral extraction)	Haulage (Transportation)	Processing	Marketing	Others (Please specify)

(iii) What type of mining do you carry out? (You may tick as many boxes as possible)

Surface Mining	Underground mining	Alluvial mining	Others (Please specify)

(iv) What type of mineral do you mine?

Aggregates	Gemstones	Metallic ores	Dimension stones	Industrial Minerals	Others (Please specify)

(v) How do you operate?

As a lone miner	In a group with other miners	As an Employee under a company	Others (pls specify)

(vi) Do you belong to any mining cooperative society?

Yes	No

(vii) If you chose "yes" to question (vi) above, is your cooperative society registered with the Nigeria Ministry of Mines and Steel Development?

Yes	No	I do not know

(viii) Are you a registered member of any mining government-approved association?

Yes	No

Section C: Licensing

(i) Do you have a valid license for your operation?

Yes	No

(ii) If you chose "No" to question (i) above, please select the possible reason(s) why you have not obtained a license.

It is too costly	My application for a licence was declined	My application for a license is still under processing	I do not know how to apply	I am not interested in applying	Other reason(s) (please specify)

(iii) If you chose "yes" to question (i) above, what type of licence do you operate with?

Reconnaissance license	Exploratory license	Small-scale mining lease	Large-scale mining lease	Others (please specify)

(iv) If you chose "yes" to question (i) above, were you required to show proof of reserve before your mining license was approved?

Yes	No

Section D: Reserve Estimation

(i) Do you know ore reserve estimation?

Yes	No

(ii) If you chose "Yes" to question (i) above, please indicate how you learned about ore reserve estimation.

In school	Based on field experience	Organised workshops/seminars	Others (please specify)

(iii) If you chose "Yes" to question (i), was there ore reserve estimation at your present mine site before your operation commenced?

Yes	No	I am not sure

(iv) If you chose "No" in question (i), please state how you operate without carrying out reserve estimation

we searched/explored for the ore, and we started work	Instinct based on experience	We moved in after the former owners of the site left	Others (pls specify)

Section E: Finance/Funding

(i) What is the primary source of funding for your operation (please tick only one option)?

Personal savings	Support from friends	External Sponsors/Buyers	Government loans	Cooperative loans	Commercial/Microfinance bank loans	International donors	Others (please specify)

(ii) Apart from your primary source of funding selected in question (i) above, state your other source(s) of funding (tick as many options as applicable).

Personal savings	Support from friends	External Sponsors/Buyers	Government loans	Cooperative loans	Commercial/Microfinance bank loans	International donors	Others (please specify)

(iii) If you chose "Commercial/Microfinance bank loans" in questions (i) or (ii) above, was proof of adequate ore reserve a requirement used by the bank before granting your loan application(s)?

Yes	No

Section E. Fund Utilisation

(i) Which of the following projects do you need funds for in your operation? (Tick as many options as applicable)

Acquisition of license	Bush clearing	Road grading	Sinking of shaft	Equipment purchase	Haulage (Transport)	Ore Processing	Others (Pls specify)

Section F. Loan requirements

(i) Based on your current level of productivity, what interest rate can you afford to pay on loans provided for your operation?

0%	<5%	5-10%	11-20%	>20%

(ii) Which of the following do you have as guarantors that can help you sign loan applications?

Just my family members	A senior civil servant (grade 12 above)	A political office holder	A royal father	An employee of a blue-chip company (e.g., oil companies)	Others (pls specify)	None

(iii) Do you have a feasibility report on your mining operation?

Yes	No

Section G: Mine closure

(i) Do you have plans for reclaiming this site after closing your mining operation at this site?

Yes	Yes, but not documented	No

APPENDIX B

Permissions for the sources of data

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

7 September 2021

Reference number: EBIT/132/2021

Mr OD Eniowo
Department: Mining Engineering
University of Pretoria
Pretoria
0083

Dear Mr OD Eniowo

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Approval is granted for the application with reference number that appears above.

1. This means that the research project entitled "Credit-risk prediction for a viable artisanal and small-scale mining operation" has been approved as submitted. It is important to note what approval implies. This is expanded on in the points that follow.
2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Research Ethics Committee.
3. If action is taken beyond the approved application, approval is withdrawn automatically.
4. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.
5. The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof K.-Y. Chan
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

BANK OF INDUSTRY

Bank Of Industry Limited
23, Marina, P. O. Box 2357, Lagos-Nigeria.
Tel: +234 1 2715070-99.
E-mail: info@boi.ng **Website:** www.boi.ng **RC: 2019**

July 27, 2021

Mr. Olushola Daniel Eniowo
Mineral Sciences Building
Room 5-50
Department of Mining Engineering
University of Pretoria
Pretoria, South Africa

Dear Sir,

PERMISSION LETTER FOR DOCTORAL RESEARCH

This letter serves to notify you that your request to carry out your research in the Bank of Industry Ltd (BOI) is hereby granted.

Accept my warm regards.

Yours faithfully,
For: Bank of Industry Ltd

Christian
Ekwenna Christian
Deputy Manager

FEDERAL MINISTRY OF MINES AND STEEL DEVELOPMENT

Block 11 &12, Ayo Fayose Housing Estate , Ado-Afao Road, Ado-Ekiti

Telephone: 08037785765

E-mail: ogenramos2002@yahoo.com

MID/EK/OP/079/Vol. 1/41

29th July, 2021.

To Whom it may concern,

PERMISSION FOR RESEARCH WORK
RE: ENIOWO OLUSHOLA DANIEL (18396594)

May I humbly refer to the above named, research student who is working on Credit-risks prediction for a viable artisanal and small scale mining operation and to also mention that he is a very close allied for some years now and to affirm without any reservation that Eniowo Olushola Daniel, is hardworking, honest and of high intellectual capacities, which he is translating to a research work for the purpose of advancing his knowledge on the PhD programme.

2. In view of the above facts, you are to accord him all the much needed assistance in your artisanal and small scale mining operations of your sites for the purpose of advancing his PhD programme

3. Please accept my warm regards.

Engr. Naku E. R.
Federal Mines Officer,
Ekiti State.

NIGERIA
The Heart of Africa

MMSD

Appendix C

R-codes for developing logit models

Development of Logit models for prediction of the probability of ASM operation accessing formal loans

by

Olushola Daniel Eniowo

Generating simple logit model using knowledge of ore reserve estimate to predict access to formal fund

1. **importing the dataset into RStudio**

```
library(readxl)
df <- read_excel("C:/Users/Dan Eniowo/OneDrive/Desktop/PhD Documents/PhD Dataset.xlsx")
View(df)
```

2. **converting variables to factor**

```
df$formal.fund <- as.factor(df$formal.fund)
df$KnwResEst <- as.factor(df$KnwResEst)
```

3. **removing NAs**

```
nrow(df)

## [1] 96

df <- df[!(is.na(df$formal.fund) | is.na(df$KnwResEst)),]
nrow(df)

## [1] 93
```

4. **subsetting the dataset**

```
myvars <- c("formal.fund", "KnwResEst")
df1 <- df[myvars]
```

5. **installing dplyr library**

```
library(dplyr)

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

6. **removing data to achieve unbiased dataset**

```
df2 <- df1 %>% slice(52:93)
```

7. **randomising dataset**

```
df3 <- dplyr::sample_n(df2, 42)
```

8. **developing the logit models**

```
logistic <- glm(formal.fund ~ KnwResEst, data=df3, family="binomial")
summary(logistic)

##
## Call:
## glm(formula = formal.fund ~ KnwResEst, family = "binomial", data = df3)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.72140  -0.66805   0.02502   0.71809   1.79412
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)   -1.3863     0.5590  -2.480 0.013143 *
## KnwResEstyes   2.6101     0.7559   3.453 0.000554 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 58.224  on 41  degrees of freedom
## Residual deviance: 43.598  on 40  degrees of freedom
## AIC: 47.598
##
## Number of Fisher Scoring iterations: 4

library(dplyr)
```

9. **installing library for graph plotting**

```
library(ggplot2)

## now we can plot the data
predicted.data <- data.frame(
  probability.of.formal.fund=logistic$fitted.values,
  formal.fund=df3$formal.fund)

predicted.data <- predicted.data[
  order(predicted.data$probability.of.formal.fund, decreasing=FALSE),]
predicted.data$rank <- 1:nrow(predicted.data)
```

10. **plotting predicted data against formal fund status of miners**

```
    ## Lastly, we can plot the predicted probabilities for each sample accessin
g
    ## formal funding and color by whether or not they had formal fund
    ggplot(data=predicted.data, aes(x=rank, y=probability.of.formal.fund)) +
      geom_point(aes(color=formal.fund), alpha=1, shape=4, stroke=2) +
```

```
      xlab("Index") +
      ylab("Predicted probability of getting formal fund")
```

```
    ggsave("formal_fund_probabilities.pdf")
```

```
## Saving 5 x 4 in image
```

Generating logit model using all statistically significant variables to predict access to formal fund

1. **Importing dataset into RStudio**

```
library(readxl)
df <- read_excel("C:/Users/Dan Eniowo/OneDrive/Desktop/PhD Documents/PhD Dataset.xlsx")
View(df)
```

2. **converting variables to factor**

```
df$formal.fund <- as.factor(df$formal.fund)
df$KnwResEst <- as.factor(df$KnwResEst)
df$hav.gua <- as.factor(df$hav.gua)
df$afford.int <- as.factor(df$afford.int)
df$min.coop <- as.factor(df$min.coop)
```

3. **removing NAs**

```
df <- df[!(is.na(df$formal.fund) | is.na(df$hav.gua) | is.na(df$min.coop) | is.na(df$KnwResEst) | is.na(df$afford.int)),]
nrow(df)
```

```
## [1] 86
```

4. **subsetting the dataset**

```
myvars <- c("formal.fund", "KnwResEst", "hav.gua", "afford.int", "min.coop")
df1 <- df[myvars]
```

5. **installing dplyr library**

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

6. **removing data to achieve unbiased dataset**

```
df2 <- df1 %>% slice(45:86)
```

7. randomising dataset

```
df3 <- dplyr::sample_n(df2, 42)
```

8. developing the logit models

```
logistic <- glm(formal.fund ~ ., data=df2, family="binomial")
summary(logistic)

##
## Call:
## glm(formula = formal.fund ~ ., family = "binomial", data = df2)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -2.19371  -0.41226   0.04141   0.43471   2.23945
##
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)     -4.413      1.416  -3.118  0.00182 **
## KnwResEstyes     2.003      1.030   1.945  0.05182 .
## hav.guayes       1.991      1.020   1.951  0.05102 .
## afford.intyes    1.238      1.123   1.102  0.27041
## min.coopyes      2.732      1.046   2.611  0.00904 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 58.224  on 41  degrees of freedom
## Residual deviance: 27.623  on 37  degrees of freedom
## AIC: 37.623
##
## Number of Fisher Scoring iterations: 5

library(dplyr)
```

9. installing library for graph plotting

```
library(ggplot2)

## now we can plot the data
predicted.data <- data.frame(
  probability.of.formal.fund=logistic$fitted.values,
  formal.fund=df3$formal.fund)

predicted.data <- predicted.data[
  order(predicted.data$probability.of.formal.fund, decreasing=FALSE),]
predicted.data$rank <- 1:nrow(predicted.data)
```

10. plotting predicted data against formal fund status of miners

```
    ## Lastly, we can plot the predicted probabilities for each sample accessin
g
```

```
    ## formal funding and color by whether or not they had formal fund
    ggplot(data=predicted.data, aes(x=rank, y=probability.of.formal.fund)) +
      geom_point(aes(color=formal.fund), alpha=1, shape=4, stroke=2) +
      xlab("Index") +
      ylab("Predicted probability of getting formal fund")
```

```
    ggsave("formal_fund_probabilities.pdf")
```

```
## Saving 5 x 4 in image
```