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Original article

Urban mining versus Artisanal and Small-Scale Mining (ASM): An interrogation of their contribution to sustainable livelihoods in sub-Saharan Africa

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ABSTRACT

Electronic waste (e-waste) recycling and artisanal and small-scale mining (ASM) are activities that are increasingly finding uptake as a means of providing livelihoods in the face of high unemployment, especially in the developing world. Informal e-waste recycling is typically practiced by individuals or groups of people who collect end-of-use and end-of-life electronic and electrical equipment which they can repair or refurbish and resell as well as break down to sell valuable components. E-waste recycling is a form of urban mining; thus, the intention of the paper is to draw parallels between this form of mining and artisanal gold mining. Artisanal miners extract virgin minerals while 'urban miners' reclaim metals from various waste streams. Both sectors are characterized by high levels of informality and their activities are largely practiced as a means of livelihood. We used the sustainable livelihoods framework (SLF) as a tool to draw this comparison based on available literature on the two sectors, complemented by anecdotal field data. It was found that the livelihood capitals are similar between the two sectors and that there are strong similarities in the vulnerability contexts, with a notable difference being that informal ASM, which has a more significant interaction with the natural environment, places higher demands on natural and physical capital such as land and water pollution and limited access to transport. Recommendations are made on how to strengthen the different capitals of sustainable livelihoods in the hope that these will inform policy decisions on informal sector activities.

1. Introduction

In many developing countries informality is increasingly becoming a socially and economically constituted process that mediates how the majority of individuals deal with poverty and livelihood challenges (Oteng-Ababio, 2018; Owusu-Sekyere and Twumasi Amoah, 2020). In sub-Saharan Africa (SSA), more than 80% of workers find their livelihoods in the informal sector (Nguimkeu and Okou, 2020). The International Labour Organisation (ILO) (1993) defines the informal sector as one that has a primary objective of generating employment and incomes to the persons concerned, and where labor relations exist, they are based mostly on casual employment, kinship, or personal and social relations rather than contractual arrangements with formal guarantees. Informal enterprises are not registered under any form of legislation and do not pay tax. While it is acknowledged that informality has its challenges, it is recognized that in SSA the informal sector plays a key role in the economic growth of these countries (Heintz and Pollin, 2008; Aryeetey, 2011; Etim and Daramola, 2020). Informal employment is plagued with challenges, some of which include lack of social protection, and exposure to unsafe workspaces. The minerals and metals industry in SSA has not been spared from informal operations.

The electronic waste (e-waste) recycling sector generates and keeps in circulation what becomes classified as secondary materials. When dismantled and sorted, e-waste makes up various valuable fractions that can be processed to recover value and responsibly dispose of its toxic elements. Metals, both ferrous and non-ferrous, constitute part of the key value fractions from e-waste and make this waste stream attractive for gainful recycling. Gold and copper, found in some fractions of e-waste, are regarded the major value carriers and while most informal operations do not typically process this waste fraction to produce pure

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metal themselves, the value of the e-waste collected is nonetheless pegged against the valuable metal fractions it contains. Concentrations of these two metals in the printed circuit board (PCB) value fraction vary with reports, with copper in the range of 12.5%–28%, while gold is in the range of 68 g/t–1120 g/t, notably higher than concentrations found in primary ores (Prestele, 2020).

The informal and often illegal nature of e-waste recycling, as well as rudimentary practices common in this practice, are like that of the more established yet still informal and often illegal practices in artisanal and small-scale mining (ASM). Similar to informal e-waste recycling, informal ASM is largely done as a means of a livelihood and it has often been criticized for being a poverty trap for the miners (Hilson and Garforth, 2012; Kumah et al., 2020; Schwartz et al., 2021). A 'poverty trap' describes an economic system from which impoverished people find it extremely difficult to escape, owing to several factors such as lack of access to capital and/or credit, no social plans to fall back on, and poor education. The system requires significant capital injections in order to attain a critical minimum asset threshold allowing people to successfully educate their children, build upon their productive assets, and move ahead economically over time (Gore, 2003; Carter et al., 2007; Hilson and Garforth, 2012). An apparent difference between informal ASM and informal e-waste recycling is the geographical context aligned to the two. ASM is largely practiced in remote and rural settings, while e-waste recycling is a form of urban mining and, as the name suggests, is largely practiced in urban areas.

In this paper, the contributions of informal e-waste recyclers and informal artisanal miners towards sustainable livelihoods are reviewed in parallel through the sustainable livelihoods framework (SLF) by describing, reviewing, and comparing various parameters in both livelihood activities. It is acknowledged that there is vast literature on the two livelihood activities independently. However, a systemic juxtaposition and analysis of the livelihoods has previously not been presented. Therefore, this paper provides insights on the similarities between the two sectors and highlights opportunities for shared learning between them.

A SLF approach was taken in the research described in this paper. The intention was that the SLF theory would assist in structuring and organizing information and in gaining a holistic understanding of the sustainability of livelihoods from the two sectors. Since there is diversity in the value streams of e-waste, and many different commodities are produced through ASM, for the purposes of this paper we focus on gold as the value metal generated in both sectors.

We posit that there are significant commonalities between the two sectors in terms of the assets required to make operations sustainable and the risks faced as well as the strategies that can be implemented towards further developing the sectors. Sections 1.1 and 1.2 briefly describe the e-waste recycling and ASM sectors, respectively, while Section 1.3 provides an overview of the SLF which is later employed to describe and analyze results from this study.

1.1. *E-waste recycling*

A generic e-waste recycling value chain can be categorized into four steps: collection, dismantling and sorting, pre-processing, and processing. While formal operations for e-waste recycling exist across this value chain, informal operations contribute significantly to the growth of this sector. Informal operations largely occupy the lower tiers of the value chain with individuals or small groups involved in collecting, refurbishing and reselling or/and dismantling and sorting of e-waste and subsequently selling the different value fractions to formal players who

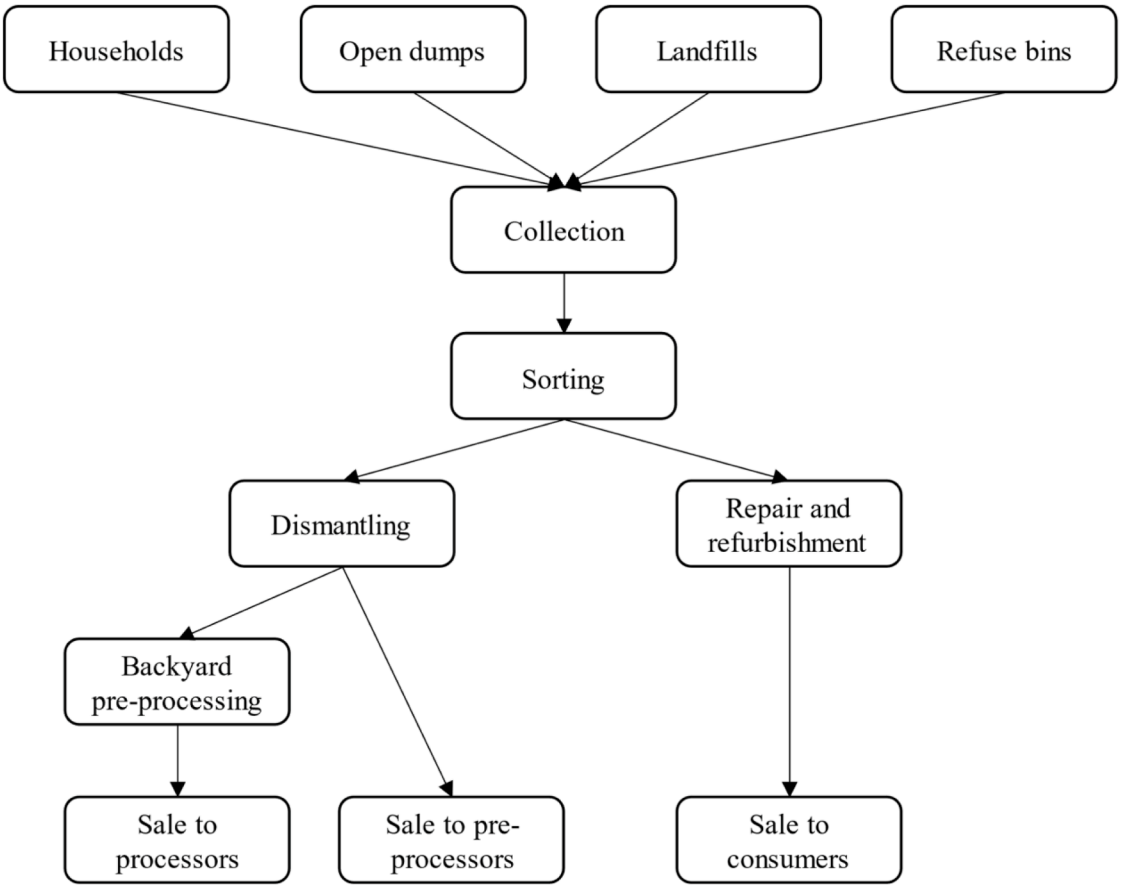

Fig. 1. The generic informal e-waste recycling process. The information shown was synthesised from Ogungbuyi et al., 2012; Acquah et al., 2019; Asibey et al., 2020; Nuwematsiko et al., 2021.

either process these to recover value or are better resourced to facilitate trade in bigger and sometimes international markets.

Informal collectors recover e-waste from a variety of sources such as households, refuse bins, landfills and open dumps (see Fig. 1). The collected e-waste is sorted, with items viable for life-time extension sent to repairers and/or refurbishers (Amankwah-Amoah, 2016; Acquah et al., 2019; Asibey et al., 2020). The remaining units are then dismantled in preparation for sale. Depending on the targeted value fraction, some pre-processing may be practiced using rudimentary approaches. For example, open burning of cables to recover the contained metals has been observed in some SSA countries (Osibanjo and Nnorom, 2007; Grant and Oteng-Ababio, 2012; Karcher et al., 2018; Nuwematsiko et al., 2021). Disposal of fractions for which informal recyclers have no use remains a problem as recyclers often dump these fractions or leave them behind wherever dismantling would have taken place.

1.2. Artisanal and small-scale mining

There is no single definition of ASM, but it is generally accepted as the labor-intensive extraction and processing of minerals using simplistic technology. Like informal e-waste recycling, ASM is largely practiced as a means of livelihood by people who have no alternative forms of employment. Depending on the commodity mined, ASM operations involve prospecting, excavation, mineral processing to upgrade the concentration of the targeted metal and, where technologies are accessible, the extraction and recovery of the metal which is then sold to the market. Globally, over 44.5 million people are working directly in ASM – with an estimated 30% being women (Delve Database, 2022). SSA hosts over 13 million artisanal miners, and the sector supports over 60 million people (World Bank, 2020; Delve Database, 2022). ASM produces 20% of the global gold supply, with countries such as Ghana and Zimbabwe producing significant amounts of their country's gold output through ASM (IGF, 2017). The ASM sector has grown significantly from employing 13 million to 30 million people in 1999 and 2014, respectively, to the present-day statistics which sit at just over 44.5 million people (IGF, 2017; Delve Database, 2022). In the face of growing unemployment and the urban to rural re-migration driven by an accelerated shrinking of the job market linked to the Covid-19 pandemic, even more people are likely to practice ASM in the near future (Seccatore et al., 2014; Boillat and Zähringer, 2020; Telmer and Kroll, 2020; FAO, 2021). Artisanal and small-scale gold mining is common in SSA, with its original focus on alluvial gold deposits, largely through the mining of riverbeds and creeks. This type of gold is in its native form and is generally easy to process, making it possible for the miners to extract, recover and sell a relatively pure product. Both the mining and the processing approaches have remained underdeveloped and rely on practices that pose a significant threat to human health and the environment. Since ASM operations are labor intensive, they require miners to be of strong physical health, but the rewards from such operations are marginal.

With the growth of the artisanal and small-scale gold mining sector, other types of gold deposits are being mined, and operations have moved to include underground mining. This increases the safety and health risks and leads to reduced productivity due to the more complex approaches to mining and processing of the mined ore. ASM is characterized by itinerant labor, and the general profile of the miners describes them as poorly skilled, under-resourced, remotely located subsistence miners with limited or no opportunity to build capital for investment in their activities.

The role of women in artisanal mining has been the subject of several studies which highlight the significant contribution to livelihoods made by women's participation in the sector (Blair et al., 2017; Hinton, 2011; Weldegiorgis et al., 2018; Lyster and Singo, 2020; Arthur-Holmes and Abrefa Busia, 2021). Similar to other sectors, income from women participating in ASM is largely used to support households directly; i.e., it is used for essentials such as food, school fees and health care. Yet, ASM continues to reflect gendered work patterns with women largely playing peripheral roles which earn them low incomes when compared to their male counterparts (Weldegiorgis et al., 2018; Arthur-Holmes and Abrefa Busia, 2021). Furthermore, women, as the primary caregivers, find themselves overwhelmed in the face of challenges such as those that arose from the closure of schools and ill-health as a result of the Covid-19 pandemic. This severely diminished women's ability to work, and the knock-on effects on household incomes and hence livelihoods cannot be overstated (Hentschel et al., 2002; Boillat and Zähringer, 2020).

1.3. Sustainable livelihoods and the sustainable livelihoods framework

Using a sustainable livelihood approach is an all-encompassing method to assess and provide an understanding of the numerous complexities of livelihoods, and the limitations and opportunities to which they are subjected (CeDEP, 2020; Majale, 2002). The SLF presents the main factors that affect people's livelihoods, and typical relationships between these factors (CeDEP, 2020; DFID, 1999). The sustainability element in the SLF implies that the "individuals or communities who are utilising their skills and assets to survive, can confront and overcome moments of stress and/or crisis, and that they are able to maintain or even improve current and future skills and assets without exploiting their supply of natural resources" (UNDP, 2017). The SLF can be used in both planning new development activities and assessing the contribution to livelihood sustainability made by existing activities, with the framework particularly drawing attention to core influences and processes as well as emphasizing the multiple interactions between the various factors which affect livelihoods (DFID, 1999). The SLF, which has been graphically represented as shown in Fig. 2 adopts a systems approach to its understanding of livelihoods, and this is conceptualized through four dimensions (Hoadley and Limpitlaw, 2004; DFID, 1999; Schenck et al., 2017): (1) livelihood assets – the goods and capital which people need; (2) livelihood strategies – the means by which people earn a living; (3) vulnerability context – the context for which a particular kind of support is designed; and (4) transforming structures and processes – factors which could strengthen subsistence resilience to moments of stress and crisis.

2. Materials and methods

This research was conducted through a mixed-methods approach (Pluye and Hong, 2014); i.e., a literature study in conjunction with fieldwork. This allowed for an affirmation of the literature findings. Fieldwork on ASM was conducted in Zimbabwe while that on e-waste recycling was conducted in South Africa. These are two SSA countries in which the respective sectors are well developed.

Research on ASM has been widely reported, covering numerous topics related to this paper, e.g., livelihoods (Hoadley and Limpitlaw, 2004; Laari, 2018; Mkodzongi and Spiegel, 2019), policy (Hilson, 2006; Sippl and Selin, 2012; Gronwald and Singo, 2020), sustainable development (Hentschel et al., 2002; Baah-Ennumh and Forson, 2017), and sustainable livelihoods case studies (Baah-Ennumh and Forson, 2017). This was reviewed through reading and analyzing data and insights in peer-reviewed journal publications and grey literature. Literature sources were identified based on coverage of the subtopics relevant to the SLF. For example, papers on ASM policy were reviewed and the information from those papers was then discussed in relation to its contribution to sustainable livelihoods. It should be pointed out that a great deal of literature on ASM is published in the 'grey' literature – mainly reports from development agencies, legal commentary and government reports. The literature study was complemented with site visits to two artisanal and small-scale gold mines as well as to an artisanal and small-scale gold mining processing site in Zimbabwe in March 2021. During the site visits, information was gathered through job shadowing of the artisanal gold miners and unstructured discussions on

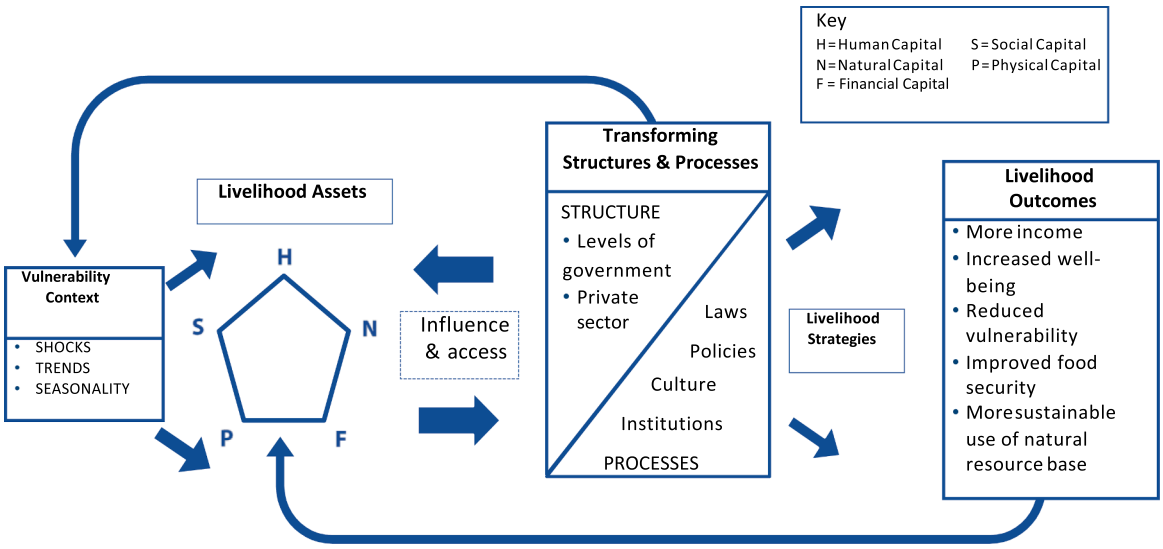

Fig. 2. Sustainable livelihoods framework. Reproduced from DFID (DFID, 1999).

their activities and experiences. Selection of the sites was based on a site meeting the general criteria of ASM operations as defined in Section 1.2, safety and security concerns for the researchers in the field, as well as owners/managers on site willing to host the researchers.

In comparison to ASM, there is relatively little literature (both in journals and in grey literature) available for informal e-waste recycling, with a stronger focus on the end-processing of the collected material rather than the collection itself. Thus, this knowledge was bolstered using fieldwork. Fieldwork the form of surveys which consisted of both quantitative and qualitative questions. A team of six fieldworkers was trained to administer the questionnaires to informal e-waste pickers in Cape Town, South Africa. Pickers were interviewed at buy-back centers and scrap metal dealerships where they are known to conduct their activities and sell their wares. Convenience sampling was used as we did not have an indication of the population. The questionnaires explored the motivation of e-waste pickers for participating in urban mining, their activities and their incomes. Data collection was conducted from 10 May 2021 to 27 May 2021 and altogether 110 surveys were conducted.

The information gathered was then systematically analyzed according to the SLF described in Section 1.3. Livelihood aspects and vulnerability contexts were drawn into Tables 1 and 2 for easy visual comparison. Fig. 3 provides an illustration of the research approach.

We acknowledge the differences in approach used for information gathering between the two sectors. In examining the ASM aspects of the study, we relied on literature studies and unstructured discussions, while in gathering information on e-waste recycling, we employed structured questionnaires and complemented the information thus obtained (from the questionnaires) with a literature survey. The key information gathered remained the same, as can be seen in the tables related to the results (Table 1 Table 2).

3. Results and discussion

The results and discussion are presented following the SLF. Livelihood assets as informed by the fieldwork and literature study are presented in Table 1 and insights on these livelihood assets are presented and discussed in the context of the table. The vulnerability context of the livelihood assets is presented in Table 2 and is discussed in sub-sections 3.4.1 to 3.4.3. Finally, the transforming structures and processes are presented and discussed in Section 3.5.

3.1. Livelihood assets

Livelihood assets refer to the resource base of different households, and are classified into five categories: human, social, financial, natural, and physical (CeDEP, 2020; Schenck et al., 2017; DFID, 1999). An improved access to these livelihood assets is a desirable outcome of good livelihood strategies. Table 1 summarizes the five categories of livelihood assets, with the column titled "Aspect" referring to the factors which individually or in combination can impede a population's ability to develop or sustain particular types of livelihood capital.

3.2. Livelihood assets in e-waste recycling

3.2.1. Human capital

The informal e-waste sector is characterized by low-income and impoverished workers. Results from surveys in Cape Town indicate mean weekly earnings of US$ 37.08 with a median of US$ 26.03. It is primarily dominated by men (Grant and Oteng-Ababio, 2019; Adanu et al., 2020; Asibey et al., 2020), with women found to constitute 25% of the workforce in Cape Town. Women in Cape Town were found to earn less than men, i.e., US$ 22.97/week, while men earned a mean of US$ 41.79/week. Informal waste recycling does not have any barriers to entry. As such it is often dominated by people without educational qualifications who are trained on the job.

Participation in the informal e-waste sector is a physically demanding job that entails a great deal of walking, lifting, carrying, pushing and pulling (Acquah et al., 2021). In Agbogbloshie, Ghana, 62 of 70 collectors surveyed reported walking at least four hours per day (Acquah et al., 2021). There are a number of practices that increase the risk of hazards for workers; these include unsafe dismantling and processing practices such as breaking and smashing, as well as open burning. Consequently, informal workers in the e-waste industry are subject to many health risks, including respiratory issues, neurological and genetic disorders and musculoskeletal disorders (MSDs) (Yu et al., 2017). A study conducted among informal waste workers in Agbogbloshie, Ghana, found that they are at high risk of developing MSDs and work-related disabilities (Acquah et al., 2021). Despite the hazards posed by their work, e-waste workers often do not wear personal protective equipment (Oteng-Ababio et al., 2014; Acquah et al., 2019; Acquah et al., 2021; Adanu et al., 2020).

High incidences of injuries and muscular pain can potentially result in abuse of pain medication, as reported in Ghana, where workers were observed drinking a mixture of tramadol and energy drinks, stating that

Table 1
Livelihood assets in informal ASM and informal e-waste recycling.

	ASM	Informal E-Waste Recycling
Aspect	**Human capital**	
Health	Health threats from the work environment (injury from mining, poisoning by toxic chemicals in processing). Pre-existing health conditions based on quality of life as affected by poverty.	Health threats from the work environment (physical injuries from dismantling, risks from working in landfills or digging into waste bins, etc).
Education	People of various education levels participate, from those without high school qualifications to those with postgraduate degrees.	Dominated by people without high school qualifications.
Knowledge and skills	On-the-job training and skills development. However, skilled people stand to make more income.	On-the-job training and skills development.
Capacity to work	Physically demanding manual work. It requires good physical health.	It requires good physical health; however, physical demands are dependent on type of work.
	Natural capital	
Land	Mining and processing practices can degrade land and contaminate soil. Accessing mines can involve trespassing on private property, and/or operating in abandoned shafts.	Dismantling and pre-processing methods can result in soil contamination. The area in which to dismantle and process is often inaccessible.
Water	Processing practices contaminate water quality, and siltation can reduce the capacity of water bodies. Access to water can be a threat to doing the job.	Dismantling and pre-processing methods can contaminate water courses and sources.
Trees and forest products	This contributes to deforestation through harvesting trees for mine construction, and clearing land for mining and camping close to mining sites.	
	Social capital	
Networks and connections	Poor organisation amongst miners due to itinerant nature of work. Poor collective representation, with few ASM associations. Practices largely informal, no consistency from law enforcement in dealing with practitioners. Activities are sometimes criminalised. Mixed relations with communities. Accepted as a source of economic activity but shunned for related social ills.	Workers form relationships for cooperative working. Collective representation present in some regions. Mixed relationships with law enforcement. At times they are treated as criminals due to the association of e-waste with stolen goods. Mixed relationships with residents. Some respect the role informal waste pickers play in waste diversion while some view them as a nuisance.
	Physical capital	
Transport	Transport required as areas are typically not easily accessible except where ASM coexists with large-sale mining or in close proximity to other businesses.	Limited access to transportation necessary for the collection of e-waste. Workers primarily rely on makeshift trolleys.
Shelter	Itinerant nature leads to makeshift shelters on active sites.	Impoverished workers are forced to live in informal shelters as they cannot afford formal housing.
Energy	Mines are located remotely and off the grid, thus they primarily rely on off-the-grid and expensive energy such as petrol/diesel-fuelled generators.	
Water supply infrastructure	Mines are located in remote areas with no established water supply or sanitation.	While working, workers have limited access to water and sanitation.
Tools and technology	Largely employ rudimentary tools and outdated and inefficient equipment and technology.	Largely employ rudimentary tools.
	Financial capital	
Income	Low and inconsistent incomes, hand to mouth.	Variable and low incomes.
Wages	Unstable wages based on production, profit share with claim owners and profit share as payment for access to and use of equipment.	No formal wages. Unstable wages/incomes.

Table 2
Livelihoods vulnerability context of informal e-waste recycling and informal ASM.

Informal E-waste Recycling	Informal ASM
Shocks	
COVID-19 lockdowns	COVID-19 lockdowns
Gangsterism influences	Armed conflict
Closure of buyback centers	Injuries and death (fairly common in the excavation stage)
Working conditions make workers vulnerable to illnesses and injuries	Violence
Weather limitations to mobility (e.g., rain)	Police raids
	Gangsterism influences
	Weather limitations to mobility and general outdoor work environment
Seasonality	
Weather limitations to mobility; e.g., rain	Higher risks of mine collapse during rainy season
	Mines flood and are inaccessible in rainy season
	Poor water supply, poor productivity during drought
Trends and changes	
Fluctuating commodity prices	Limited access and uptake of new technologies resulting in limited productivity among other things
	Fluctuating commodity prices
	Increased pressure for responsibly mined gold
	Evolving requirements and costs for formalization

it enabled them to work longer periods with less pain (Acquah et al., 2019). Insights drawn from Cape Town attested to the physically demanding nature of the job, with workers indicating they use push carts (commonly re-purposed supermarket shopping carts) to transport their wares and walk from place to place to collect and sale.

3.2.2. Social capital

Workers may choose to form connections and networks amongst each other, electing to work together. For example, in Accra, workers were observed to collect e-waste in groups (Oteng-Ababio et al., 2014). When it comes to dismantling, workers may choose to work alone or in pairs as observed in Cape Town and Accra (Amankwaa, 2013). The presence and type of collective representation depends on the region. For example, in South Africa there are two associations – the South African Waste Pickers Association and the African Reclaimers Organisation – while in Nigeria the Scrap Metal Dealers Association of Nigeria also represents e-waste collectors and recyclers (Manhart et al., 2011).

In Cape Town, workers reported mixed experiences when interacting with the public: some members of the public treated them well, while

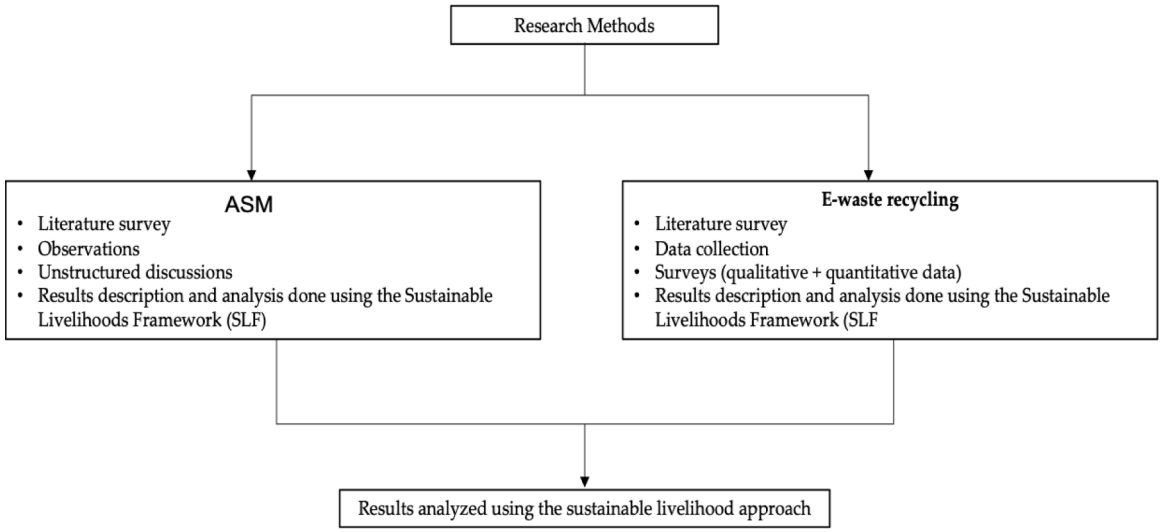

Fig. 3. Illustration of research approach.

others were openly hostile. Similarly, mixed experiences were reported by those who had interacted with the police. The hostile treatment is thought to be due to the perception that they are criminals and that they may steal from private or public properties. However, when it came to the buyers, the workers largely reported good experiences, with a few reporting unpleasant ones.

3.2.3. Natural capital

The methods employed in the dismantling and pre-processing of e-waste result in environmental pollution. For example, burning of cables and plastic casings causes the release of harmful pollutants such as dioxins, furans and ozone-depleting substances into the air (Agyei--Mensah and Oteng-Ababio, 2012; Karcher et al., 2018; Alabi et al., 2021). Burning of e-waste can also result in heavy metal contamination of soils (Ouabo et al., 2019; Alabi et al., 2021). Soil is also contaminated via the indiscriminate release of hazardous liquids such as acid from batteries (Karcher et al., 2018; Adanu et al., 2020). Indiscriminate dumping of e-waste can contaminate water courses through the leaching of hazardous substances (Alabi et al., 2021). Water bodies can also be contaminated by run-off from contaminated soil when it rains.

3.2.4. Physical capital

Results from Cape Town showed that due to the economic status of the workers, they often do not have access to secure shelter. In Ghana, workers were observed to live on or adjacent to the site in makeshift shelters (Asibey et al., 2020; Yang et al., 2020). Due to the informal nature of these settlements, there is often little or no access to potable water, sanitation, and electricity. In addition, workers have limited access to transport and often rely on trolleys or pushcarts for transportation of their collected goods (Manhart et al., 2011; Oteng-Ababio et al., 2014; Acquah et al., 2019).

For dismantling, informal workers often employ rudimentary tools such as hammers, chisels and screwdrivers (Acquah et al., 2019; Adanu et al., 2020). The lack of finance is a major constraint to the adoption of more advanced technology, and it has been reported that their income does not allow for savings, let alone the purchase and upkeep of tools (Adanu et al., 2020).

3.2.5. Financial capital

Participation in the informal e-waste economy is often viewed from a positive perspective that sees it as creating jobs and contributing to the economy (Tocho and Waema, 2013; Oteng-Ababio et al., 2014). However, it is important to take into consideration the quality of the jobs and the associated wages. In 2013, Tocho and Waema (2013) estimated that in Kenya, informal e-waste recyclers could earn US$ 217.12–US$ 325.50 per month. In Agbogbloshie, Ghana, Oteng-Ababio et al. (2014) estimated weekly wages of US$ 14.00–US$ 24.50, and in Kumasi, Ghana, workers who recovered copper had an average monthly earning of US$ 224.22 (Asibey et al., 2020). However, when these authors analyzed the distribution of this income among the different actors, they found that dismantlers – who also conduct burning – were the highest earners (US$ 372.2), while refurbishers and collectors earned considerably less with US$ 135.56 and US$ 122.76 respectively. Larger variations in income were observed in Cape Town in 2021, with workers self-reporting monthly incomes ranging from US$ 2.80–US$ 1400. The variability in incomes is influenced by a number of conditions, including degree of activities, market conditions, and global and local economies, as well as access to financial resources and technology to compete (Grant and Oteng-Ababio, 2019; Asibey et al., 2020). In comparison to other actors in the value chain, informal collectors are considered to be at the bottom rung of the financial ladder (Oteng-Ababio et al., 2014; Asibey et al., 2020).

3.3. Livelihood assets in artisanal and small-scale gold mining

3.3.1. Human capital

Due to its largely informal and unpoliced nature, the only determinant of who enters the ASM job market is the artisanal goldminers' physical ability to work. Men, women and children work in ASM, with men being the ones who carry out the more difficult tasks, although children have also been employed and sometimes for the purposes of accessing disused underground mines through pathways that are too narrow for adults to pass through (Hentschel et al., 2002; Hilson, 2010; K4D Report, 2017). There is significant participation of women in ASM, with some countries reporting as high as 50–60% women participation (Weldegiorgis et al., 2018; Buss and Rutherford, 2020; Arthur-Holmes and Abrefa Busia, 2021).

Table 1 shows that health, education, capacity to work, knowledge and skills are the five aspects that have been found to impact human capital in artisanal and small-scale gold mining The most popular definition of health is that articulated by the World Health Organization, which describes health as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (Grad, 2002). In the ASM sector, emphasis is placed only on the physical ability and hence the physical health of individuals to do the work. Observations made in the field study affirmed that the work entails digging hard ground and rocks, and lifting and pushing heavy rock materials. Moreover, the work is dangerous due to unstable underground structures,

tools and equipment not ergonomically designed, exposure to dust and toxic chemicals, extremes of temperature, and poor lighting (Hentschel et al., 2002; Leung and Lu, 2016; Stewart, 2020). Considering ASM workers are largely poor, and are remotely located, general access to health care is limited, which further compromises their ability to access remedy in the face of work-related injuries and disease. Artisanal and small-scale gold mining is largely dominated by people with low levels of education: a case study conducted in Malawi showed that only 21% of the miners had at least a secondary-level education (Haundi et al., 2021). However, it was found from fieldwork done in Zimbabwe that due to dwindling formal employment opportunities, people even with university-level education are now entering the informal artisanal and small-scale gold mining sector, typically in some form of partnership with artisanal miners from the host communities. While the terms of partnerships are not always clear, these arrangements allow for the transfer of knowledge and skills. Although there is no prior knowledge and skills requirement to enter the sector, due to the increasing complexity of ore bodies that are mined it is expected that there will be higher gains for miners with better understanding of the processes involved. This could explain why the partnerships seem to work and could be regarded as a way of adapting for the sector, considering that it offers avenues for artisanal and small-scale gold mining to continue to operate in the face of changing ore bodies and other technical challenges.

3.3.2. Natural capital

Inherently, mining in whatever form is not sustainable. It leaves behind a scarred and ruined environment, limiting the ability to return to non-mining-related livelihood activities that are typically practiced, such as agriculture. Operating without mine planning or design and with most of the mineral processing occurring close to water bodies, informal artisanal and small-scale gold mining has significant environmental impacts. Some of the most significant effects are deforestation, changes in landscape structure, influence over geo-morphological processes and hydrological river regime, chemical pollution of soil and water courses, and influence on soil production capacity (Macháček, 2019). Since ASM is increasingly becoming a source of livelihood for many people in SSA, it is expected that as more people enter the sector the impacts on natural capital such as land, minerals, biodiversity and water will also increase. Besides the negative impacts, actors in the sector are also affected by access to natural capital. A common challenge is that of access to land for the purposes of mining. Land tenure for mining purposes is unclear to miners in many remote areas. Also, it is recognized that artisanal and small-scale gold mining negatively affects water resources as the gold ore processing technologies that are employed require significant amounts of water; thus, poor access to water is a limiting factor to successful operations. Typical processing of gold ores includes a gravity concentrating step, and in ASM, sluicing coupled with mercury amalgamation is the most prominent method (Hinton et al., 2003; Drace et al., 2012; Veiga et al., 2014). Cyanidation of the tailings from gravity concentration and mercury amalgamation is becoming a growing practice and this leads to further pollution of water in the disposal of cyanide-rich tailings (Velásquez-López et al., 2011; Drace et al., 2016). Residual elemental mercury from panning tailings is oxidized during cyanidation, further mobilizing it. This leads to pollution of water sources even in areas outside the proximity of the artisanal and small-scale gold mining sites. Observations and discussions during fieldwork in Zimbabwe revealed that informal miners took their ores to processing centers for milling, gravity concentration and mercury amalgamation and left their tailings to the processing center owner for further processing via cyanidation. In the processing step, the processing centers used borehole water and water extracted from their own shafts during mining. They indicated that their site consumed 7 500 L of water per 20 tonnes of ore, and that they lost 30% of this to evaporation and spillages. Similar information was not shared with regard to mercury losses, so it was not established how much was lost be it via spillage or evaporation in the roasting step.

3.3.3. Social capital

Due to its largely itinerant nature, informal artisanal and small-scale gold mining suffers from poor organisation, with miners sometimes working in groups that easily and quickly disband when word of new or richer deposits comes up. This also translates to poor collective representation among miners who consequently experience poor representation at decision-making levels. However, there are some artisanal and small-scale gold mining associations and cooperatives – for example the Mthandazo Women in Mining association in Zimbabwe and the Ghana mining association in Ghana. Also, in Kenya, general mining rights to ASM are granted to adult Kenyan nationals as long as miners are members of associations or cooperatives (Fisher, 2018). In the Zimbabwe case study, it was noted that miners without a registered claim did not belong to any association, neither did they mention wanting to join one.

3.3.4. Physical capital

ASM is mostly practiced in remote areas, and these areas suffer poor access to infrastructure as governments normally neglect the development of the remote areas. Except where they co-exist with large-scale mining, ASM areas do not have developed road networks. As a consequence of the itinerant nature of labor and poor access to financial capital, hardly any effort is made to set up secure buildings for shelter, and workers simply camp near the sites in makeshift tents. It is thus not surprising that there is typically no water supply or provisions for sanitation. Due to the rural and remote nature of this kind of mining, ASM activities occur in areas that are off the national electricity supply grids and are reliant on carbon-based fuel generators and energy stored in batteries. While the use of cellular phones is prevalent in most communities, this mode of communication is only effective in areas where there is network coverage and it is therefore not accessible in many remote locations. Consequently, ASM in these areas relies on word of mouth for communication. Word of mouth appears to spread reasonably fast in the sector (Jønsson and Bryceson, 2009; Bryceson et al., 2020), especially among informal operators whose itinerant nature is fueled by word of new or richer deposits in neighboring areas.

Although gold processing has been practiced for over a century and some of the technologies are well established, ASM is subject to poor access to context-specific technology. It is known that ASM is underdeveloped; thus, it is still reliant on rudimentary technologies in both the processing and mining sectors. Where mechanization exists, outdated equipment is usually employed. This has to do with a lack of access to capital and poor knowledge amongst miners.

3.3.5. Financial capital

The largely informal nature and poor self-organisation of most ASM activities translate to poor access to financial capital. Miners in this sector often have no collateral and may not be well acquainted with formal procedures for applying for support from financial institutions (Bannock Consulting, 2005; Ledwaba, 2017). Technological interventions that do not translate to immediate profits are typically driven by not-for-profit organizations and governments. These are hardly sustained and become redundant, examples being mercury retorts and fume hoods which were donated to aid the reduction of mercury emissions in the roasting step that then produces gold sponge from the gold-mercury amalgam (Sippl and Selin, 2012; Malehase et al., 2017; Esdaile and Chalker, 2018). Miners are focused on the monetary gains and neglect to invest in their mining and processing tools. The reasons for this are related to the ASM poverty trap: since miners are typically unskilled and unable to invest in their operations, they continue to use simplistic technology, which leads to low productivity and subsequently low income and exacerbation of poverty (Hilson, 2012).

Results from the fieldwork affirmed that artisanal and small-scale

gold mining operates using various 'business models', some of which involve a site owner who 'employs' diggers at no fixed wage or contract. The diggers do the work and once the gold sponge is obtained, it is sold, and profits are shared with the site owner or processing center owner. Some cases involve a funder who supplies the equipment and fuel and provides food for the diggers. The profits are then split three ways among the diggers, the site owner and the funder. This is basically a no-work no-pay arrangement, and there is no pension or plans for retirement and no medical insurance. In some instances, artisanal gold miners work for themselves and the miner keeps whatever profits they make. Since they are itinerant, diggers, especially those with families, almost always send remittances (Boukaré, 2020; Makhetha, 2020). Earnings from artisanal and small-scale gold mining vary widely and are inconsistent. Bryceson and Jønsson (2010) reported an average of about US$ 150 monthly income in Tanzania, for a sample of 108 small-scale miners, but with very wide variation (going from close to US$ 0 to over US$ 500) while Bansah (2019) estimated monthly earnings around US$ 250, ranging between US$ 163 and US$ 1 220 in Ghana. Miners visited during fieldwork in Zimbabwe chose not to disclose their income, although they allowed us to observe a one-week cycle in which 143 grams of gold sponge was produced through mercury amalgamation. The price fetched for the gold produced varies depending on where they sell their product: either to a state-owned entity or to informal buyers.

3.4. Livelihoods vulnerability context

Trends, shocks and seasonality are factors from the external environment, and people have limited or no control over these factors, which can intensify or destroy livelihood assets (Serrat, 2017; Arthur et al., 2016). Thus, the ability of livelihoods to recover from their vulnerability contexts is key to sustainable livelihoods (Scoones, 1998). While Table 1 outlines comparisons between the capitals in informal e-waste recycling and informal ASM, Table 2 outlines the vulnerability contexts for the livelihood capitals.

3.4.1. Shocks

Livelihoods' resilience to shocks is important and key to both livelihood adaptation and coping (Davies, 1995). Results from fieldwork in both informal ASM and e-waste recycling revealed that both sectors suffer as a result of the influences of gangsterism or criminal syndicates. In informal artisanal and small-scale gold mining, gangsters demand payment for protection, and/or are predatory in the sense that they monitor activities, and once there is indication of rich deposits, they push out miners and may rob them by confiscating the mined ores (Debrah and Asante, 2019; Mkodzongi and Spiegel, 2019; Nesvet, 2020). In Cape Town, gangsters were reported to have some influence: they demanded a 'tax' from waste pickers working in informal e-waste recycling to allow them to operate in the 'gang's territory'. This results in loss of already mined or collected, and sometimes already processed materials and translates to loss of either entire incomes or reduced earnings for the workers who already live mostly on incomes below their countries average cost of living (Mawowa, 2013; Tschakert, 2016; Hwehwe and Thebe, 2021).

Chitaka et al. (2022) report that informal e-waste recyclers – e-waste pickers in particular – earn below the minimum wage, and thus it would be expected that recovery from shocks would be a challenge to livelihoods despite the low barriers to entry in the sector. The closure of buy-back centers owing to poor business at the peak of the Covid-19 pandemic has compelled informal recyclers to travel longer distances in order to find a market. This state of affairs may also translate to an added 'tax' when they have to trade outside of their designated areas, thus possibly making their operations less viable. The 'tax' is often paid to gangsters operating in an area to allow the pickers to work without harassment.

The COVID-19 lockdown exemplifies a shock that brought both artisanal and small-scale gold miners and e-waste recyclers to their knees, leaving operators unable to mine or collect e-waste, and those that already had something to sell had no access to markets. This implies that the people working in these sectors, and mostly lived from hand to mouth, immediately lost their only source of income. Pholoto (2021) reported that in South Africa, exclusion of informal waste recycling activities from services allowed to operate during Covid-19 related restrictions had resulted in severely disrupted livelihoods. Informal ASM, on the other hand, did not suffer a downright ban in countries such as Tanzania, but due to limited mobility, both locally and internationally, production was significantly compromised, and miners were forced to sell their gold to local buyers at low prices (Jaillon et al., 2019). Muthuri et al. (2021) reported that in Ghana and Kenya, Covid-19-related restrictions had significantly increased the vulnerabilities of artisanal miners. ASM also suffers other factors such as the effects of armed conflict (Singo and Seguin, 2018; Mkodzongi and Spiegel, 2019) and changing regulations, which sometimes criminalize ASM, leading to police raids (Nyame and Grant, 2014; Chipangura, 2019), and injuries or death on the job (Stemn et al., 2021).

3.4.2. Seasonality

Both informal e-waste recycling and ASM are labor-intensive activities, involving outdoor work in the face of changing weather conditions. E-waste pickers walk long distances and carry out their sorting and dismantling activities outdoors. Their activities are thus significantly affected by weather conditions, with workers usually unable to work or finding their health more compromised in the rainy season and in harsh in winter. Artisanal and small-scale gold mining, on the other hand, coexists with subsistence farming in some areas (Cartier and Burge, 2011; Maconachie, 2011; Hilson, 2016). This was supported by results from the Zimbabwe site visits, where it was found that farming was done in the rainy season and focus shifted to informal ASM during dry months to complement incomes. However, it is acknowledged that ASM compromises arable land, with some authors considering it a threat to food security (Asamoah et al., 2018). Therefore, when there are no agricultural activities, the rainy season is characterized by increased shocks to ASM livelihoods, since the mines are inaccessible due to flooding and/or the ground becoming unstable, thus leading to mine collapse. Hilson (2016) discussed the seasonal nature of ASM, showing linkages between ASM and subsistence farming. However, despite the mentioned downside, Hilson and Garforth (2012) reported ASM to be a more secure supplementary income that supports the 'diminished viability of smallholder farming' (Hilson and Garforth 2012). Another notable factor is the impact of climate change on weather patterns thereby further contributing to weather-driven shocks in both informal e-waste recycling and informal ASM.

3.4.3. Trends and changes

ASM traditionally exploited alluvial gold on riverbeds and mined free-milling gold ores which are relatively easy to process and recover profitably. Since this is a finite resource, these types of deposits are depleting and more complex ores that require more specialized processing are being mined. This situation leads to poor recoveries translating to low productivity, especially among informal ASM miners with scant knowledge and poor access to technologies that may be suitable for their ore types. Alfonso et al. (2019) reported on the importance of mineralogical knowledge in the sustainability of artisanal and small-scale gold mining in Peru. No similar research has been done in SSA but one could argue that trends from large-scale mining reflecting the mining of more refractory gold ores would apply in the artisanal and small-scale gold mining sector in this part of the globe as well. Literature study and fieldwork on Zimbabwe revealed that alluvial gold mining, which was previously acceptable, was outlawed in 2006 (Spiegel, 2015; Chipangura, 2019).

Informal e-waste recyclers also experience challenges related to sourcing e-waste. Resource availability varies in different regions and municipalities. For example, in South Africa some landfill operators

allow access to landfills while others do not. Furthermore, in August 2021 South Africa implemented a ban on the disposal of e-waste to landfills in accordance with a timeline for the ban of various hazardous waste streams that was published in NEMWA regulations (NEMWA 2008, 2013). This may result in systems being put in place that exclude informal e-waste recyclers.

With regard to monetary gains, informal ASM experiences changes in prices at which the mineral output is sold. This varies with changes of commodity prices in international markets, changes in exchange rates, and economic booms or busts for which informal miners cannot plan (Majale, 2002). It follows that the impacts of down-cycles in commodity prices trickle down to the miners who then suffer reduced earnings from their exploits. Further to this, in Zimbabwe, miners reported different pricing depending on whom they are selling to. Miners alluded to feeling insecure about selling to the state-owned entity Fidelity Printers and Refiners (FPR) although FPR has the mandate to buy gold from ASM on a 'no questions asked' basis.

Like ASM, informal e-waste recyclers are vulnerable to market fluctuations in commodity prices. As the commodity prices change, the effects trickle down from the formal e-waste recyclers to the informal sector that supplies them. Insights from the fieldwork done in Cape Town revealed that in general, there is no uniformity in pricing when informal recyclers sell their wares. The recyclers were limited in choice as to where they sell due to difficulties in accessing some buyback centers; i.e., they would need to incur some transport costs and/or pay 'tax' to a different gang that has control of the area in which the alternative buyback center is located.

Another factor that is well intended and has many merits but is also a threat to informal ASM is that of responsible sourcing frameworks and due diligence schemes, examples being those advocated for by the Organisation for Economic Co-operation and Development and the London Bullion Market Association (OECD, 2016; Singo and Seguin, 2018; Mancini et al., 2021). Informal miners are not adequately equipped to jump through all the hoops that would enable them to access the benefits of participating in these schemes, and in some cases, they may find the requirements crippling to their processes. Furthermore, while the schemes have helped miners in fetching competitive prices for their exploits, they have been criticized for offering 'largely technical solutions to profoundly political problems' (Sovacool, 2019). Jaillon et al (2019) conducted a baseline study to assess the impact of due diligence programmes in the Eastern Democratic Republic of Congo and found that some human rights and labor violations were observed less frequently in areas that implemented due diligence programmes compared to areas that did not, but that such programmes did not circumvent human rights and environmental challenges occurring in the sector. Van der Merwe (2020) points out that refining is a critical point in the gold supply chain, and that a way for the refiners to handle the cost of due diligence is by shortening the supply chain through buying gold mainly from a few industrial suppliers. This would leave out the 20% global gold supply that comes from ASM, which is considered high risk in terms of due diligence requirements. Therefore, while it is recognized that the current discourse on formalizing the sector and the drive to implement due diligence frameworks are all geared towards making the sector sustainable, the approach to their implementation should seriously take into account the context of these operations (Spiegel, 2015; De Haan, 2018; Singo and Seguin, 2018; Uribe, 2020; World Bank, 2020). There is a risk of pushing informal miners further into poverty and creating opportunities for better informed and well-resourced middlemen to facilitate trade.

3.5. *Transforming structures and processes: e-waste recycling and artisanal mining*

The various livelihood capitals provide clarity on the micro-level realities of urban miners and artisanal and small-scale miners. However, it is important to consider the national, regional, and global influencing structures and processes that impact the livelihoods of individuals. The five capitals of livelihoods suffer consequences of the prevailing structures and processes. Therefore, the sustainability of the livelihood assets depends on the transformative capacity of the structures and processes to respond to context-specific requirements.

The transforming structures include the powerful public and private stakeholders, such as the various spheres of governance (national, provincial and local) and the private sector that develop and implement various processes (Serrat, 2017; Vikblad and Lekare, 2019). Transforming processes are the laws, policies, cultures, and institutions that have an impact on livelihood outcomes (Serrat, 2017; Laari, 2018). These processes include the sustainable use of natural resources, increased income, food security, well-being, and the reduction of the vulnerability of the livelihood to shocks, trends and seasonality, as well as informal norms, rules, customs and culture that influence the implementation of more formal processes. The transforming structures and processes enable or deny access to supporting assets and will be context dependent, with legal frameworks shifting the transformative power of stakeholders (Serrat, 2017). This section of the paper discusses commonalities seen in the structures and systems of informal e-waste recycling and ASM in SSA with reference to the two case studies.

There are two groups of commonalities in the SSA region regarding transformation processes and structures in informal ASM and e-waste recycling. The first group of commonalities is related to internal structures and processes and the second group concerns external structures and processes. Regarding internal structures and processes, both informal ASM and e-waste recycling often have little or no incorporated organizational structure, leaving people without the capacity to claim mining rights and/or the ability to monitor the prices received for their extracted or reclaimed resource (Baah-Ennumh and Forson, 2017; Omar, 2018). However, e-waste recyclers have been found to be more organized through cooperatives and associations when compared to their ASM counterparts. Certain informal internal rules and norms govern the culture and activities of both sectors. An example was given in Section 3.4.3 of Zimbabwe's artisanal and small-scale miners who have the opportunity to sell to official gold buyers. The gold buyers do so on a 'no questions asked' basis, which can be seen to legitimize the activities of the informal ASM sector in Zimbabwe (Hlungwani et al., 2021).

The second group of commonalities is related to the influence from external structures and processes. These relate largely to the legal system and the powerful public and private stakeholders who are able to make decisions that affect the livelihoods of informal e-waste recyclers and artisanal miners. In SSA there are very few legal systems that accommodate, support and guide the development of ASM and e-waste recycling (Hlungwani et al., 2021; Maes and Preston-Whyte, 2022). Where law has been developed, as is the case in South Africa, it often criminalizes/restricts ASM and e-waste recycling activities (Tschakert, 2009; Khan, 2016) and regulates them as destructive, dangerous and environmentally unsound. For example, in South Africa e-waste is considered hazardous waste, and requires a hazardous waste management licence for any waste activity (National Environmental Management: Waste Amendment ç, 2014). Therefore, even if recyclers only collect e-waste, they will be required to adhere to an extensive licensing process (Sadan, 2019). The perception is that the activities ought to be prevented due to the environmental and social harms (Baffour-Kyei et al., 2018; Baah-Ennumh and Forson, 2017).

Both the informal artisanal miner and the informal e-waste recycler function within legal 'grey areas' where some legal requirements may be met while others are not. The legislative burden, be it related to health and safety, environmental protections, labor relations or trade, is likely be too onerous for individuals to satisfy. The informal nature, functioning outside of the legal framework, can give e-waste recyclers a competitive edge against formal operations when it comes to collection and preprocessing (Grant and Oteng-Ababio, 2021).

The enforcement of the law is often poor, particularly in rural areas

where artisanal mining is most often located (Hentschel et al., 2002; Bansah et al., 2016). Not only does an example from Zimbabwe's ASM show criminalization of informal ASM with miners reporting that they randomly face raids from police, but the literature also highlights its inconsistency, with the state said to vacillate between supporting and criminalizing ASM (Chipangura, 2019; Hlungwani et al., 2021). Informal recyclers in Cape Town were found to operate in urban areas where law enforcement is relatively more visible. Insights from the interviews indicated that the recyclers were ambivalent regarding the law, with most indicating that they got into trouble with law enforcement who tend to assume that the collected goods were stolen and also find the recyclers' approach in the selling of the refurbished goods to be in violation of the Second-hand Goods Act (Second-Hand Goods Act No. 6, 2009).

Weak international and domestic institutions do not only have an impact on the livelihood assets – they also affect global and regional value chains (Scholvin et al., 2019). For example, Ghana's e-waste sector is challenged by weak domestic customs and legislative gaps covering import from developed countries that enable illegal dumping of e-waste under the guise of second-hand used electronics (Grant and Oteng-Ababio, 2019; Bogale, 2011). This influx of electronic and electrical equipment into African countries can be seen as a positive activity that bridges a digital divide and contributes to a global and regional repair, reuse and recycling market (Khan, 2016). However, reaping this benefit is only possible with capacity building at the international and domestic institutional level to ensure due diligence and quality control from exporting and importing jurisdictions (Bogale, 2011; Khan, 2016). The ASM sector, on the other hand, contributes significantly to the extraction of raw materials from SSA. The lack of institutional controls results in great loss of revenue for the state and consequently affects the overall development and well-being of the country (Hentschel et al., 2002; Bansah et al., 2016; World Bank, 2020).

In SSA, plans to include and support e-waste recyclers and artisanal and small-scale miners through laws have increased. There has been a significant increase in legislation related to e-waste in Africa. Ten new e-waste related laws, regulations and policies were developed over three years (2018–2020). For example, in South Africa, an ASM policy has been introduced with the intention to formalize artisanal miners, and Extended Producer Responsibility (EPR) regulations have been developed to regulate e-waste recyclers. Informal e-waste recyclers and informal ASM are currently criminalized in South Africa, and the people involved are marginalized, partly due to the high legal barriers and societal perceptions (Maphosa and Maphosa, 2020; Ndlazi, 2021). However, as previously mentioned, in May 2021, South Africa published its second draft ASM policy for public commentary, a move which can be regarded as taking strides towards the formalization of ASM and driving it to operate in a sustainable manner. The policy, which has since been published for implementation (National Gazettes, No. 46124, 2022), also aims to have the ASM sector contribute to the formal economy through taxes, royalties and job creation. On the other hand, Zimbabwe's mining policy framework does not define ASM, neither is there a legal injunction that governs it (Hlungwani et al., 2021). This leaves the transformation of the sector to be opaque with several verbal stances taken that seemingly legitimize ASM (Chipangura, 2019; Hlungwani et al., 2021). Furthermore, ASM appears in some of the countries' roadmaps to economic recovery – such as the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZIMASSET) – which set a target to establish 500 syndicates comprising 2 500 registered small-scale miners in the period 2013–2018 (ILO, 2017). Such moves indicate governments' acknowledgement of the sector's contribution and require Zimbabwe to follow the likes of South Africa, Ghana, Rwanda, to name but a few African countries that have developed legal instruments to govern ASM.

Regarding developments in informal e-waste recycling: in South Africa, the Department of Forestry, Fisheries and Environment published the EPR regulations coupled with guidelines and a national waste management strategy. The regulations, guidelines and strategy all highlight the need to integrate informal waste collectors and reclaimers into the formal waste economy (DEFF and DSI, 2020; NEMA, 2021). How and whether this integration will be accomplished is yet to be seen, and the regulations offer no vision in this regard.

These types of process interventions were largely welcomed; however, similar concerns regarding transforming structures are evident throughout the continent. For example, in South Africa, concerns were raised during public consultations with both the ASM and e-waste recycling sectors regarding the respective legal developments. The concerns centered on the potential exclusion of foreign nationals when requiring South African identification, or some form of registration (MACUA and WAMUA, 2021; CoP: Waste to Value, 2021), as well as the lack of clarity on skills development in the process of formalizing the sectors (Chege and Kengni, 2021; CoP : Waste to Value, 2021).

There are two overarching recommendations for transforming structures and processes within the context of e-waste recycling and ASM livelihoods to encourage resilience building. The first is that resilience building ought to be a bottom-up approach, with laws informed by existing informal structures. Resilience building often includes introducing a level of organisation to allow for monitoring and evaluation. An effective system is dependent on how the structures are governed and the processes enforced to include what is functioning in the system and to manage what is not. For example, the informal e-waste recycling hub in Agbogbloshie Ghana is a dynamic and complex matrix of collectors, aggregators, repairers, scrap-yard owners and various other players that have established relationships (Grant and Oteng-Ababio, 2021). However, most introductions of organisation appear top-down, with regulation securing formal firms and disincentivizing smaller operators by establishing insurmountable legal and administrative burdens (Chirisa and Nel, 2021; Grant and Oteng-Ababio, 2021). Multiple case studies have confirmed the necessary involvement of informal, community-based structures and processes to implement successful livelihood interventions (Maliganya, 2020; Grant and Oteng-Ababio, 2021).

The second overarching recommendation to have skills development stand as a key intervention (Cassim et al., 2016; Grant and Oteng-Ababio, 2021; Yose, 2014). A study involving seven West African countries established that even faced with external constraints such as access to finance, inadequate stable locations, and insecure basic infrastructure, enterprises are still able to grow and can organically formalize if they have the requisite skills to advance in their sector (Cassim et al., 2016). Skills is the foremost indicator for a firm's success. However, resilience and well-being in a sector will still require access to technology, credit, space, and reliable service delivery to grow into larger, more formal markets. The recommendation is that external structures need to investigate potential context-specific interventions to bolster skills development within already established networks. The skills required will depend on context. The external processes then need to actively incentivise these interventions. This approach should be preferable over the common one usually followed by external structures and systems – which is to establish preventative legal burdens to enable larger operations while further marginalising a group already in the sector out of necessity (Grant and Oteng-Ababio, 2021).

4. Conclusions

Informal ASM and informal e-waste recycling make for an interesting juxtaposition when considering that one extracts a finite natural resource and is therefore inherently unsustainable, while the other recycles and reclaims materials from waste and would thus be a good example of sustainability practice. However, there are commonalities to the drivers and challenges faced in informal e-waste recycling and informal ASM. It is recognized that both sectors contribute to livelihoods, especially to those of vulnerable people who have no alternative income sources. The livelihood capitals are similar between the two

sectors and while the vulnerability contexts do not entirely match, this study found that there were indeed similarities. The results indicate that informal ASM has a more significant interaction with the natural environment and that the sector places more demand on natural and physical assets. Furthermore, although the two sectors show similarities in the context in which their assets are under threat, ASM suffers an increased vulnerability because of shocks and seasonality largely related to natural capital. Informal e-waste recycling was found to involve dismantling and crude pre-processing, and to largely exclude actual metal recovery. On the other hand, ASM spans from prospecting to processing, and practices mercury amalgamation with limited and poor uptake of alternative processing technologies. Across both sectors a higher degree of processing would allow for better income, but it would also compromise certain aspects of human and natural capital. However, establishment of effective and sustainable processing practice is compromised by aspects of physical and financial assets.

Weak institutions were indicated to impact livelihood assets and regional value chains. However, there is an increased recognition of both sectors' potential to contribute to development. Thus, there are ongoing developments in legislation for both sectors, with governments and policy makers seeking to provide enabling legislation for the formalization and development of the sectors. Skills development and a bottom-up approach in resilience building have been identified as key enablers for transforming both sectors. Recognition of existing informal structures, introduction of a level of organization to allow for monitoring and evaluation of the sectors, and context-specific skills development within existing structures and systems are all thought to have the potential for making the livelihoods earned in these sectors to be more sustainable. Notably, despite the identified commonalities in the two sectors, the legislative effort continues to proceed in isolation. It is hoped that the comparative study presented in this paper will provide valuable pointers for a more integrated approach towards the informal sector.

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The paper is based on collaborative research between the NRF SARChI Chair in Minerals Beneficiation, Minerals to Metals Initiative, University of Cape Town, and the DSI-NRF-CSIR SARChI Chair in Waste and Society, University of the Western Cape. The paper was conceptualized jointly by all authors during a workshop. Dr T. Moyo drafted the paper, and Dr T.Y. Chitaka and Ms A. Lotter contributed sections on e-waste and the transforming structures respectively. Prof. C.J. Schenck and Dr T.Y. Chitaka were responsible for collecting fieldwork data on informal e-waste collectors and Dr T. Moyo was responsible for the ASM fieldwork. Prof. C.J. Schenck edited and reviewed the sustainable livelihoods framework and Prof. J. Petersen contributed through reviewing the overall structure and editing the paper.

Declaration of Competing Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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