Mechanisation of Alluvial Artisanal Diamond Mining: BARRIERS AND SUCCESS FACTORS

By Michael Priester, Estelle Levin, Johanna Carstens, Geert Trappenier and Harrison Mitchell
About DDI International

DDI is an international, nonprofit, charitable organization that aims to gather all interested parties into a process that will address, in a comprehensive way, the political, social and economic challenges facing the artisanal diamond mining sector, in order to optimise the beneficial development impact of artisanal diamond mining to miners and their communities within the countries in which the diamonds are mined.

A major objective is to draw development organizations and more developmentally sound investment into artisanal diamond mining areas, to find ways to make development programming more effective, and to help bring the informal diamond mining sector into the formal economy.

More information on DDI International can be found at www.ddiglobal.org, and we can be reached at enquiries@ddiglobal.org.

Abbreviations

AADM artisanal alluvial diamond mining
AM artisanal mining / miner
APEMIN Apoyo a la Pequeña Minería (ASM support program in Bolivia)
ARM-FLO Association for Responsible Mining and Fair Trade Labelling Organisation
ASM artisanal small-scale mining
ATPEM Assistance Technique au Petit Exploitant Minier (Madagascar)
BGR Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources), Germany
BR Brazil
CAR Central African Republic
c.t. Carat (1 ct = 0.2 g)
DDI Diamond Development Initiative
DRC Democratic Republic of Congo
EC European Commission
EITI Extractive Industries Transparency Initiative
FONEM Fondo Nacional de Exploración Minera, Bolivia
GCD Ghana Consolidated Diamonds
GH Ghana
GRATIS Ghana Regional Appropriate Technology Industrial Service
GTZ Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
GY Guyana
KP Kimberley Process
MCDP Mwadui Community Diamond Project
MEDMIN Medio Ambiente y Minería (ASM support program in Bolivia)
MSDP Mineral Sector Diversification Programme (Zambia)
MSM medium scale mining
NGO Non-Governmental Organisation
OSH Occupational Safety and Health
PASMI Projet d’Appui au Secteur Minier
PMMC Precious Minerals Marketing Corporation
PPP Pequeños Proyectos Productivos (Support program with ASM component in Colombia)
PRIDE financial services provider to the personal and small micro medium enterprise markets in Zambia
SAESSCAM Small-scale-mining technical assistance and training service, DRC
SAM Sustainable Artisanal Mining (Support Programme in Mongolia)
SDC Swiss Agency for Development and Cooperation
SL Sierra Leone
SSM small-scale mining
UAP Unité d’apprentissage et de production
UNDP United Nations Development Program
US$ United States Dollar
USAID United States Agency for International Development
UV Ultraviolet
WB World Bank
WGAAP Working Group on Alluvial and Artisanal Producers
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1 INTRODUCTION

At present the vast majority of artisanal alluvial diamond mining (AADM) around the world is done by small groups of people using inefficient techniques and rudimentary tools such as shovels or sieves to dig and sift through alluvial deposits. Low yields and under-productivity constrain the miners’ and the sector’s development potential and leave AADM at the political and economic margins, in the informal sector. Encouraging artisanal miners to formalise rarely works without tying this to a sustained programme of active encouragement and clear economic benefits. The economic opportunity offered by mechanisation is clear and technical solutions available are manifold, yet few miners mechanise.

It is for these reasons that the Diamond Development Initiative (DDI) commissioned this study in order to inform the Kimberley Process Working Group on Alluvial and Artisanal Producers (KP WGAAP) of the potential effectiveness and socio-economic impacts of using mechanisation as a route to encouraging the formalisation of AADM.

The report draws on existing, though unfortunately limited, documented experiences of mechanisation in addition to Projekt-Consult’s own experiences, and case studies commissioned especially for this study on mechanisation in a number of country contexts. The case studies, covering Guyana, Brazil, Guinea, Ghana, Democratic Republic of Congo (DRC) and Sierra Leone, were chosen to demonstrate positive and negative experiences of mechanisation projects and ‘self-mechanisation’ attempts.

For the purposes of this study, the authors have taken mechanisation to be **the process of creating and deploying specialised equipment that increases the power of human operators by increasing the work outcome relative to the physical human input.**

1.1 Desired Development Impacts

There are three main reasons why authorities and development agencies might encourage mechanisation in artisanal mining: to increase productivity and maximise profit from a non-renewable resource; to enable or encourage rationalisation of production, so aiding legalisation and formalisation; and to improve the living and working conditions of artisanal miners.

If the aim of an intervention is indeed to help AADM contribute more to development, then mechanisation alone will not work without addressing the related social, economic, political, and legal aspects necessary to make mechanisation a success. This means that a strategic approach will be needed to ensure that mechanisation fulfils the higher objectives of formalisation and development.

1.2 Methodology

This report has been compiled by Michael Priester and Johanna Carstens of Projekt-Consult GmbH and Estelle Levin of Estelle Levin Limited with contributions from Geert Trappeniers and Harrison Mitchell. It is based on field- and desk-based case studies, which were compiled by various international and local experts. Unfortunately, there is very little documented experience of mechanisation projects, that does exist has been included herein. However, the study additionally draws on Projekt-Consult’s experience of projects including mechanisation components. The case studies of Guyana, Brazil, Guinea, Ghana, DRC and Sierra Leone were chosen to demonstrate positive and negative experiences with mechanisation projects and “self-mechanisation” attempts.

◆ In **Guyana**, the research was carried out by Marieke Heemskerk and Geert Trappeniers. Marieke interviewed stakeholders from
government and the diamond sector during six days in July 2010. Geert, who successfully mechanised a small scale diamond operation in Guyana, provided a case history of this project.

◆ In Brazil, Shawn Blore drafted previous experiences from mechanisation of alluvial diamond mining in the Coromandel area and compared it to the situation of other AADM countries (Guyana and Sierra Leone) in June 2010.

◆ Guinea and Ghana were visited by Yves Bertran Alvarez, who spent six days in each country in June 2010 to investigate the issue.

◆ Sierra Leone was covered by Estelle Levin, Babar Turay and Harrison Mitchell. Harrison consulted stakeholders in Freetown over one day in June 2010. Babar, a local expert, consulted key stakeholders in the diamond mining areas over six days, also in June 2010. This assessment was completed by a desk compilation of experiences by Estelle Levin, who has worked since 2004 on AADM in Sierra Leone.

◆ DRC was covered by Nicholas Garrett, Ghislain Lokonda Yausu and Geert Trappeniers. Nicholas discussed the barriers and success factors for mechanisation with local interview partners over two days in June 2010. Ghislain, a local expert working with the Congolese NGO CENADEP, supported the study by interviews with key stakeholders over three days, also in June 2010. Geert, who successfully mechanised a small scale diamond operation in DRC, provided a case history of this project.

Initially, it was assumed that projects supporting the mechanisation of the ASM sector had existed in all countries. However, during the course of the research it became clear that in most countries, any mechanisation that had occurred was either self-driven or initiated by medium-scale mining companies cooperating with artisnals. The only documentation on a project made available to the team was a summary of an unsuccessful mechanisation project in DRC carried out by SAESSCAM.

There are three main reasons why authorities and development agencies might encourage mechanisation: to increase productivity and maximize profit from a non-renewable resource; to enable or encourage rationalization of production; and to improve the living and working conditions of artisanal miners.
2 CURRENT MINING PRACTICES AS A STARTING POINT FOR MECHANISATION

The potential for mechanisation rests primarily on the nature of the deposit, the hydrological conditions and current mining practices. An assessment needs to define points at which alternative equipment could be introduced, and what types of equipment might be suitable. But the mechanisation potential also rests on who the miners are and why they are mining. For example, AADM is done not only by men but by women, children and the elderly, by different ethnic groups, by people with specific educational or employment backgrounds, and so on. Knowing the demographic composition of the mining population can influence what type of mechanisation is optimal. Further, there are different types of AADM determined by the reasons for which people are mining: rush AADM; temporary (emergency) AADM; isolated AADM; seasonal AADM; and traditional all year round AADM. A miner who mines professionally as his principal livelihood is more likely to wish to mechanise than someone doing it on a seasonal basis to supplement his/her farming income, for example.

Mechanisation alone, without a strategic approach that takes into account social, economic, political and legal aspects of alluvial artisanal diamond mining, will not lead to formalization and development.

2.1 The Actors

The situation varies greatly between different countries and even between different mining regions within the same country. In general, the following actors shall be considered: Labourers (diggers, gravel transporters, washers), Gang leaders (Group chiefs), Site chiefs (mine managers), Title holders, Land owners, Buyers (intermediaries, exporters), Financers, Formal mining companies cooperating with artisanal miners, Jig owners/operators, Water providers, Earth moving service providers, Dredge owners, Hirers and sellers of equipment, Cooperatives, Government/ local mining departments. They all have different relations to others, different sources of income and differing interests. Only very few key actors, namely the financier and the site chief, actually have decision making powers and can thus directly influence mechanisation.

2.2 Mining Techniques

During the study a large number of different mining situations and technical solutions have been encountered. These differ due to the geological setting of the deposit, the hydrological conditions and the features of the sediments. The following illustration synthesises the different techniques applied and mentions the most important equipment applied.

2.3 Geology and Geography Determine the Mining Process

Regardless of the size of the operation, the geology and geographic situation and especially the hydraulic regime determine the techniques for exploitation and thus the mining process. Table 1 below gives more detail of the characteristics of diamond mining for different deposit types as well as the potential for manual and mechanised artisanal mining techniques for each deposit type.
Figure 1 – Process sequence of alluvial diamond mining
### Table 1 – Potential for manual and mechanised artisanal mining for different deposit types

<table>
<thead>
<tr>
<th>Deposit Type</th>
<th>Manual artisanal mining process</th>
<th>Mechanised artisanal mining process</th>
</tr>
</thead>
</table>
| Alluvial, eluvial or colluvial deposit on dry land | **Open pits**: Artisanal miners dig wells that can be 20 meters deep. They use picks and spades to dig and load the minerals, buckets and bags to transport them, small pumps to evacuate the water, sieves to separate the gravel, and hand-picking to select minerals. This method is the most productive and least dangerous, but still presents some risks such as rock falls and injuries with picks and spades.  
**Features for ASM**: minimal investment required so low pre-financing (limited leadtime to reach the pay gravel depending on the depth\(^1\)), operation in very small gangs possible, higher productivity in deposits with shallow overburden, continuous operation possible | Mechanised operation possible with a similar exploitation process (removal of overburden, exploitation of gravel by machinery, mechanised transport, concentration in mechanised washing plants)  
Mechanised operations require larger areas to be financially viable, but facilitate higher recovery of the deposit and systematic mining processes with backfilling, rehabilitation being more possible etc.  
With enough water available high (water) pressure monitoring and hydraulic transport is an option.  
**Features for ASM**: high investment required, large pre-financing (longer leadtime to reach the pay gravel), operation only in large gangs possible, relatively low productivity, problems with occupational safety, extremely dependant on water level (seasonal activity) |
| Palaeoplacer, old terraces, placer with thick coverage of sterile overburden on dry land | **Underground galleries**: Artisanal miners dig circular holes of approximately 90 centimeters diameter and typically up to 35 meters deep (depending on the depth of the gravel). The gravel is charged in bags or buckets at the bottom of the gallery, then evacuated with the help of a rope by a winch or pulley system, controlled by miners at the surface of the gallery. This method presents many dangers such as the lack of oxygen in the gallery, and the risk of rock falls and tunnel collapse.  
**Features for ASM**: rather limited investment required, low pre-financing (relatively short leadtime to reach the pay gravel), operation in very small gangs possible, relatively low productivity, problems with occupational safety, low recovery of the deposit | Mechanised operation requires a completely different mining process with open pit mining similar to the above mentioned solution.  
The mechanised operation is characterised by massive ground movement leading to higher costs for overburden removal and higher environmental impacts.  
Miners use motor-pumps and hoses to evacuate pits and galleries of water to enable continued access in the rainy season.  
**Features for ASM**: high investment required, large pre-financing (longer leadtime to reach the pay gravel), operation only in large gangs possible, relatively low productivity, problems with occupational safety, extremely dependant on water level (seasonal activity) |
| Alluvial deposits in rivers | **Diving**: Artisanal miners dive in rivers, often without any diving suits or breathing apparatus, and extract the gravel in buckets or bags. This is hauled to a pirogue that stays still at the surface with the help of a bag of sand thrown in the water. After prospection, the miners pan manually separate gravel from minerals found at the bottom of the river.  
**Features for ASM**: Difficult to perform, limited investment required, low pre-financing (limited leadtime to reach the pay gravel), operation in pairs possible, relatively low productivity, potentially huge problems with occupational health and safety with drowning common, dependant on water level, currents and velocity (seasonal activity) | Dredging with suction dredges or elevator dredges; use of mechanical breathing apparatus and wet-suits  
**Features for ASM**: high investment required, large pre-financing (longer leadtime to reach the pay gravel), operation only in large gangs possible, relatively low productivity, problems with occupational safety, extremely dependant on water level (seasonal activity) |
| Alluvial deposits in rivers | **Dams and dykes**: In the absence of dredges, artisanal miners sometimes build dykes with sand bags in the middle of rivers (i.e. in DRC, CAR, Sierra Leone etc.) to divert the water and extract diamonds from the dry and isolated side. This method is dangerous as many miners have drowned as a result of dam breaks.  
**Features for ASM**: high investment required, large pre-financing (longer leadtime to reach the pay gravel), operation only in large gangs possible, relatively low productivity, problems with occupational safety, extremely dependant on water level (seasonal activity) | Mechanised operations require a different mining process with dredging in the river similar to the above mentioned solution.  
Complex bedrock may require divers to maximise the recovery of the diamond bearing gravel. |

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\(^1\) May take up to three weeks to reach pay gravel
2.4 Mechanization Approaches

The introduction of mechanisation can take place at any of the three starting points within the sequence of mining and processing:

1. **Removing the overburden** - where there are thick layers of overburden which require a significant amount of time and manual labour for removal, mechanisation can significantly drive up productivity. The substitution of manual labour by earth moving machines would replace a large number of diggers or liberate them from the arduous work of overburden removal, allowing them to commit themselves more to gravel exploitation and/or diamond washing. Its cost-effectiveness, however, requires exact knowledge of the depth and geometry of the upper limit of the diamond bearing gravel layer, new systems of management and a planning for systematic exploitation and combined backfill. The removal of overburden seems to favour mechanisation due to the fact that the specific strength of earth moving machines means that the fast loading, hauling and dumping of large amounts of sediments is possible.

2. **Extracting and transporting the pay gravel** to the processing site - the mechanisation process can reduce the level of manual digging needed and thus requires new internal organisation of the pit, however the machines applied for extracting the gravel (catarpillars, baek hoes) do not work well on uneven ground and due to the high costs associated with fuel and wear and tear means they are rarely used. The mechanisation of alluvial diamond deposits on dry land with hydraulic monitoring is another option, but is often hindered by its extremely high operational cost. This mechanisation generally goes hand in hand with mechanised processing.\(^2\) In riverine deposits there is the possibility of mechanising the exploitation of the gravel by using river dredges.

3. **Diamond concentration** - manual labour can be replaced by a trommel or shaking sieve in combination with a modern jig. This method tends to have a higher recovery rate than manual processing but also requires a reorganisation of the miners.

Mechanisation – the process of creating and deploying specialized equipment that increases the power of human operators by increasing the work outcome relative to the physical human input.

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\(^2\) See Blore, 2006.
### 3 Key Factors Influencing the Mechanisation Process

The factors which determine mechanisation can be broadly organised into the drivers, i.e. what makes it desirable, and the barriers and success factors, i.e. what makes it possible, or not.

#### 3.1 Drivers for Mechanisation

The principal drivers for mechanisation are commercial, socio-cultural and environmental reasons. With the view to economics the miners expect higher returns due to the faster exploitation, less effort, higher recovery and security as well as a safety gain. This is combined with a higher social reputation and social status as a consequence of the mechanisation. Finally, miners expect to overcome seasonal limitations to artisanal mining and get access to deeper deposits. Either alone or in combination, the commercial drivers increase the likelihood and potential size of profit, so helping miners achieve greater financial gain and independence. With so much to gain, the key questions then are: what are the barriers preventing artisanal miners from mechanizing? And what are the factors ensuring success when someone does attempt to mechanise?

#### 3.2 Key Barriers and Success Factors to Mechanisation

Whilst there are indeed technical reasons why mechanisation is sometimes not possible, desirable or successful, other factors can be even more important. These include the existence or non-existence of certain political, legal, financial, cultural, organisational, or demographic conditions, or the inability of miners to access these conditions even if they do exist.

### 3.2.1 – Enabling environment

The political order in the country and the mining regions influences the potential for mechanisation by affecting the investment climate and the outlook for success of mechanisation projects (i.e. conflict or post-conflict situation vs. stable political environment with effective institutions).

The administrative requirements for formalisation potentially pose many traps for mechanisation projects. In many systems there are numerous incentives for miners to remain informal. Getting a digging operation licensed can be enormously time consuming and expensive.

The legal framework of licensing in some countries (e.g. Sierra Leone, Guinea) prohibits mechanisation for ASM licenses directly or discourages it indirectly. There are legal barriers or a complete lack of mechanisms to evolve from legalised ASM to mechanised operations. On the other hand, a legal system allowing “tributor” agreements between a title holder and ASM (such as in Ghana between GCD and the diamond mining groups) poses favourable conditions for mechanisation.

The capacity and will of local or national authorities to enforce the law influences the potential for mechanisation by affecting the investment climate. The requirement of registering equipment, excessive or informal taxation on those using machines, and corruption relating to the access or use of machines can all dis incentivise mechanisation. In countries with fragile governance structures (i.e. Guinea and DRC) the mechanisation of ASM has tended to proceed very slowly, while in countries with a stable political economy and implementation of the legal framework (i.e. Brazil and Guyana) the modernisation of exploitation is quite advanced.

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3 This covers the political environment, legal, institutional and commercial issues setting the frame for mining activities in a country.
**Access to land and land rights** (security of rights) are again important for the security of investment.

**Access to finance** is a key determinant for the possibility of mechanisation.

**Access to existing support measures** may be a determinant for mechanisation. Existing programmes to support the ASM sector, such as PMMC (buying the ASM product), GCD (providing tributor agreements to artisanal miners) or GRATIS (providing equipment) in Ghana, have already established relationships of trust with the miners and may draw on their local experience as well as on their networks.

**Existence of formal companies with a positive attitude towards artisanal miners** has proven to be the most efficient element to enhance technical development of ASM.

### 3.2.2 Socio-economic factors

The **legal status of the ASM operation** has to be considered before mechanisation. Artisanal miners have their own perspective on formalisation and frequently see a lot of advantages in the informal status. Attempting to use mechanisation as a lure for artisanal diamond miners to formalise requires additional sensitisation interventions. The **internal organisation of the artisanal miners and their socio-economic dependencies** play a key role. In African countries, particularly those recovering from conflict, the level of organisation tends to be lower than in Latin America where a culture of associations and cooperatives exists and ASM societies have more stable organisational relations.

The role of **ASM within the individual or household livelihood strategy**: Miners who regard mining as their profession and main livelihood are more likely to invest in machines; those who use it as a supplementary or seasonal activity around their other, principal livelihood (especially in the agriculture sector) are less likely to mechanise.

The level of **mobility of ASM** influences the mechanisation process. In some countries with a higher degree of mechanisation, mobile equipment adapted to the realities of local ASM operations has been observed.

The **trading chain** is an important factor to be considered for a mechanisation intervention. Buyers/traders usually have strong links with artisanal miners, often being in a superior position to them and having decisive roles in the selection of the mining processes and equipment because they pre-finance the diggers or provide them directly with equipment. Lacking marketing and diamond evaluation skills further cement these dependencies.

The **cost of labour** is an important factor for the economics of mechanisation. Research comparing the cost of labour in different countries (Brazil, Guyana and Sierra Leone) and putting it in relation to the level of mechanisation confirms the considerable impact wage levels have on mechanisation. Low cost of manual labour discourages mechanisation as the cheaper the labour, the less economic it is to mechanise.

**Real and perceived benefits or losses for key stakeholders** can incentivise or disincentivise mechanisation. Especially those influenced by miners’ perceptions might not be very obvious and therefore have to be investigated carefully.

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4 Awareness must be created that, even though the lack of finance is perceived as a crucial constraint, this is often the consequence of other constraints of the business or person, such as a lack of management skills or lack of capitalisation due to traditional repartition schemes for the revenues (Priester 2005).

5 Yves Bertran, verbal communication: this tributor system helped the ASM in Ghana a lot in getting fair payment, access to finance and having investment security. Also, from this agreement, there was considerable technical know-how transfer from the company to the tributors, which supported the mechanisation.

6 Governments tend to see mechanisation as a tool to promote formalisation. This view is not shared by the artisanal miners.

7 See country study Brazil, particularly on the duration of commercial relationships of miners and financiers, and country study DRC, particularly on the presence of vested interests, unpaid security groups, military elites etc. benefiting from the status quo and thus hindering miners to become organised in cooperatives.
General education levels and knowledge of mining specific information (i.e. legislation, best practice etc.) may influence willingness and capacity to achieve a higher level of mechanisation. Especially where mining skills have been acquired on the job in traditional artisanal operations the attitude to innovation is generally negative.\(^8\)

**Customs and traditions** can have a strong influence on the mechanisation process. Interventions at this stage must aim at changing behaviour and have to be given adequate time to have an effect.

### 3.2.3 – Technological factors

**Access to appropriate technology** is paramount: proximity of manufacture, supply, maintenance and support services, the quality of the equipment, and the adaptation of the technology to regional conditions and traditional practices determine the acceptance by the miners. In Brazil and Guyana, for instance, both countries where mechanisation is advanced, there are clearly distinguished national technology solutions developed and provided locally.

**Trust in the new technology** is important for miners to adopt it. With an unknown technology the artisanal miners often fear that material can be stolen or may disappear during processing.\(^9\) At the same time, artisanal miners do not want to waste time testing new equipment that might turn out to be useless for them. International experience from artisanal mining of various minerals shows that “Lighthouse projects” with positive experiences or proven successes of the innovation\(^10\) play an important role in the successful dissemination of a new technology.

**Knowledge about the parameters of the mining operation** is important before starting mechanisation in order to avoid unpleasant surprises.

The **level of training and know-how** in how to manage, use, and maintain the new technology determines how easily it will be adopted and how sustainable the introduction of the new equipment is.

**Security considerations** are also important when attempting to increase mechanisation of an operation. Due to increased mechanisation a higher concentration of value occurs and therefore the operations may be more prone to theft if access to machines is not sufficiently restricted, especially at the point of accessing the pay gravel. On the other hand, using machines for concentrating diamonds limits the number of people who handle them, and thus may also minimise opportunities for theft by workers.\(^11\) Here again the cooperation with formal enterprises provides extra security.

### 3.2.4 – Geographical factors

The **geological, geomorphologic and hydraulic characteristics of the deposit** influence the viability of mechanisation. These factors cannot be altered by a project. But diamond grade, size, quantity and quality, the parameters of the gravel (particle size and composition), the thickness and character of overburden, the groundwater table, the availability of surface water, the level of water during rainy and dry seasons are all enormously important in determining which mining process is optimal.

The **remoteness of the ASM operation** also affects the chances of mechanisation.

### 3.2.5 – Programmatic Design factors

Experience suggests that projects have a greater chance of success where the community is co-owner as well as beneficiary. This means that the miners also participate in project development, execution, and monitoring. If mechanisation is self-organised and community-driven it is more likely to succeed, and also has significant positive

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\(^8\) There is a strong link between the disposition to innovate and address technical challenges on the one hand and the ability to lead or accept mechanisation on the other.

\(^9\) See experiences from Latin American ASM projects on gold in Wotrub et al. (2005)

\(^10\) Many projects fail to develop trust in new technologies by experimenting prematurely with non-proven technologies.

\(^11\) This is why many people use the Plant in Sierra Leone as their machine, because diamond theft occurs most at the washing stage.
spin-off effects for the self-empowerment of the people involved, so helping communities take charge of their own development agenda.

### 3.3 The relation between the factors

The key factors influencing the mechanisation process have been sorted into external and internal as well as static and dynamic factors in an attempt to advise possible interventions. The external factors are those that are beyond the influence of the artisanal miners. An intervention tackling these factors must be addressed by other parties, such as the government, NGOs etc. Internal factors are those which are directly within the sphere of influence of the artisanal miners. Static factors will be more difficult and require more time to be changed while dynamic factors can be changed more easily.

Figure 5 below attempts to group the factors according to who has influence over the factor and how dynamic the factor is.

![Figure 2 The factors grouped according to sphere of influence and level of dynamic](image-url)
## 4 Socio-economic and Environmental Impacts of Mechanisation

Just as social, economic and environmental issues can determine the feasibility of mechanisation, so mechanisation has impacts on these dimensions. These can work with or against the objective that mechanisation contributes to development through formalisation of artisanal diamond mining. The section thus considers the socio-economic and environmental impacts of mechanisation.

<table>
<thead>
<tr>
<th>Positive impacts</th>
<th>Adverse impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For miners</strong></td>
<td><strong>For miners</strong></td>
</tr>
<tr>
<td>• Improvement in the <em>working conditions</em> of people involved in mining (including women).</td>
<td>• Increased <em>seriousness of accidents</em> where machines are not properly used or maintained.</td>
</tr>
<tr>
<td>• Minimisation of <em>child labour</em> in mining due to higher skilled labour.</td>
<td>• Risk of <em>loosing machinery and collaterals from credits</em> in the case of having lower revenues than expected with the mechanised operation.</td>
</tr>
<tr>
<td>• Decrease in <em>mining-related accidents</em> due to better mine planning and the substitution of underground mining through open cast operations.</td>
<td>• <em>Loss of jobs</em> due to the replacement of muscular with mechanical power.</td>
</tr>
<tr>
<td>• Greatly increased <em>technical skills</em> among young community members.</td>
<td>• <em>Masculinisation of the workforce and marginalisation of women.</em></td>
</tr>
<tr>
<td>• Diversification and improvement of livelihood strategies</td>
<td>• <em>Increased conflict with local communities and authorities</em> i.e. over the environmental impacts of mechanised mining</td>
</tr>
<tr>
<td>• <em>Increased human capital among artisanal miners</em> is generated through training programmes and new equipment.</td>
<td><em>Environmental impacts</em></td>
</tr>
<tr>
<td>• <em>Mechanisation can have a positive effect on OSH.</em></td>
<td>• <em>Reduced long term footprint of mining:</em></td>
</tr>
<tr>
<td>• For mining communities</td>
<td>• Higher recovery of the deposit.</td>
</tr>
<tr>
<td>• Sustainable increase in the <em>income</em> of rural community members.</td>
<td>• This improves the case for <em>reclamation and rehabilitation,</em> and where rehabilitation happens, provides the community with land that can be useful and productive through other social or economic uses, rather than a hazard.</td>
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<tr>
<td>• Improvement in the <em>provision of public facilities and services</em> in participating communities (including education, health, power, local roads).</td>
<td>• <em>Making reclamation easier.</em></td>
</tr>
<tr>
<td>• <em>Decrease in intra and inter community tensions and conflict</em> through strengthened mechanisms of dialogue, negotiation and consensus-building within participating communities, where mechanisation programmes attempt an integrated approach.</td>
<td>• <em>Introduction of environmental management systems.</em></td>
</tr>
<tr>
<td>• <em>Increased social capital in participating communities</em> as a consequence of all the above.</td>
<td>• <em>Increased environmental impact</em> unless the mechanisation is accompanied by sensitisation measures.</td>
</tr>
</tbody>
</table>

4. Final hand-picking of diamonds done by women, Ghana
5 PROJECT EXPERIENCES IN MECHANISATION AND INTRODUCTION OF NEW TECHNOLOGIES

5.1

5.1.1 – SAESSCAM, DRC
In DRC SAESSCAM has attempted the mechanisation of AADM operations by means of a dredge on which a suction pump should be installed, along with a trommel and a pedal jig. The artisanal miners, however, were reluctant to order any dredge or jig, principally because they did not see any difference in terms of productivity or working conditions between their customary techniques and the new technology being promoted. In other words, the benefits did not outweigh the costs. And due to the fact that the new and to the miners unknown equipment had no economic advantages compared to imported and proven technology.

5.1.2 – Cooperating with industrial mines in DRC and Guyana
The case studies from DRC and Guyana demonstrate that cooperation between AADM and medium scale formal enterprises is possible, especially where the geology of the placer allows organising the cohabitation in such a way that direct competition over the same deposit can be avoided.

In Guyana and DRC small- to medium sized companies encountered artisanal miners on their recently acquired concessions. Instead of chasing them away they decided to cooperate with the artisanal miners, letting them mine parts of the concession which were not viable for industrialised mining. In order not to lose the ore mined on their concession, the companies bought the artisanal miners’ production. To increase productivity and profit and thereby also improve cooperation and foster good relations with the miners the companies invested in mechanising the artisanal operations. The principal area of mechanisation was the processing stage. Thus, the recovery could be enhanced considerably, which was equally benefitting for the artisanal miners as for the companies. The companies also “mechanically” assisted the artisanal miners with the construction of access roads and transportation of materials from the mine site to the processing installation as well as the preparation for rehabilitation. In some cases, the companies also supported the mining of payable gravel with mechanical equipment. Usually, the artisanal miners paid the companies a small fee for the processing of their gravel.

5.1.3 – Lessons learned from MEDMIN, Bolivia
The MEDMIN project was a Swiss Government supported project in environmental management in ASM in Bolivia. Mechanisation of gold and base metal ASM was a means to integrate environmental measures into the mining and concentration processes and to generate funds for optimised environmental management. Key lessons were:

◆ An integrated approach is necessary, taking into account organisational, social, economic, legal, technical and environmental issues.

◆ It is essential to guarantee social, economic and environmental benefits for the miners – these “win-win” options are basic conditions for success.

◆ It is necessary to ensure the extensive participation of the miners themselves, including in the planning process.

◆ Optimum functioning of the equipment must be assured before its use. Equipment failure could easily wipe out trust that has taken a long time to build up.

◆ Due to the specific characteristics of each mining operation (type of deposit, mineralisation, size, hydrology, social-economic-cultural characteristics, etc.) a blueprint technical solution is normally inappropriate. Individual solutions always have to be developed and adapted.
When making technological changes it is imperative to execute in situ induction sessions guided by well-trained technicians, mechanics and engineers.

Dissemination of the results of successful technological changes is the most effective means for pilot operations to be replicated.

Miners must pay for their project: “It cost me, I use it and I take care of it.”

5.2 Access to Finance

Access to finance is a common struggle for artisanal miners, and especially in diamond mining where the level of production is less predictable than, say, for gold. Generally, commercial banks are not interested in artisanal miners as clients because the amount of money in question is normally too small to justify the administrative costs, and ASM tend to lack any collateral. Furthermore, banks tend not to have sufficient expertise in ASM so they are not able to successfully assess the risks and potential rewards.

Alternative sources of finance for the mechanisation of artisanal mines include: small and medium-scale companies, machine owners and equipment sellers, and local diamond buyers and ‘investors’. The latter are often a source of finance for artisanal miners, however, borrowing from them often carries the risk of the miner becoming financially dependent, and the mechanisation being limited because the financiers keep large parts of the profits on the basis of the risks involved.

Small and medium size investment by ASM/MSM cooperation proved feasible in case studies from DRC and Guyana.

In cases where ASM activities are pre-financed by private individuals such as dealers, brokers or other financiers, as is common in Guinea, Sierra Leone, DRC and more recently in Ghana, mechanisation often relies on the miner’s ability to convince the financier of the positive impact of this type of investment on production. The relative influence of the miner depends on whether s/he is viewed by the financier as a borrower or a business partner. Moreover, where financiers simply view the mines as a mere investment with no other interest in or knowledge of the process, it is much harder for the miner to make the case for mechanisation.

In a different system, which is typical for Brazil, a percentage of the final production is promised to owners of respective equipment for mechanical or technical services. A “backer” (financer) pays the miner a minimum wage and in return receives 50% of the miner’s production. In the same way, the miner can pay for services he needs (pumping water or digging out ore) by giving the owner of the equipment a percentage of his production. This way, mechanisation is possible without having large amounts of upfront capital; it also spreads the risk amongst a number of participants. The system obviously only works if production is honestly declared (reasonable level of social cohesion and trust).

Other financial options in Guyana include:

- direct ownership supported by credit schemes for the purchase of equipment by miners,
- cooperation between fellow miners.
- While research in this area is somewhat limited, it appears that payback periods tend to be long and at extremely high rates of interest, which also disincentivises miners from the long term investments necessary for successful mechanisation. Despite this, there have been examples of mutual funding whereby the investor also makes a considerable financial contribution. Another key issue is the loan guarantee which is difficult for artisanal

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12 However, in Guyana, in the wake of the high gold price, banks are “waking up” and more willing to extend loans to small- and medium-scale miners (see Country study Guyana).

13 e.g. for primary gemstone pegmatite miners in rural communities of Madagascar, ATPEM project
miners not having bankable ore reserves explored. Mutual guarantee funds\(^8\) have proven successfull in stable communities. Nevertheless, none of them was related to alluvial mining, a subsector characterised by even higher mobility, geological risk etc. Funding facilities can be more successful when based on existing, local financing/ lending systems with management by local organisations, which are embedded in the regional economic and cultural environment. Nevertheless, a minimum understanding of mining, geological risk and cost structures in the credit institution is a must. Matched funding can up success, i.e. where the investor him/herself makes a considerable financial contribution. It seems to be important to combine credit with savings in order to generate a banking culture (study on banking and credits for Ghana, GTZ and BGR). Positive examples are those where the credit facilitator steps into the risk of mining as for example FONEM in Bolivia during the 80s and 90s. This prevents the mining company from “killing” itself by over-ambitious mechanisation programmes and provides for “bankable” procedures (feasibility, reserves etc.).

5.3 The cost-effectiveness of different types and levels of mechanisation

5.3.1 Contracting/Rental vs. buying costs

In African countries there seem to exist quite well established markets for earth moving services (contractor mining, a common practice in industrialised mining operations to minimise upfront investment costs) and/or equipment hire from specialised companies. In alluvial diamond operations backhoes (and also trucks, front loaders, bulldozers, etc.) are usually rented from a company that has established maintenance capacity and a spare parts stock. Price comparisons between investment costs and leasing or service costs showed that the cost of buying or hiring equipment differs substantially from one piece of machinery to the other.\(^{14}\) According to the case study research, the relative prices for rented or leased equipment increase as one moves along the process towards the finished product (diamonds). This leads to the conclusion that a mixed bag approach to financing mechanisation with contractor mining for the overburden removal (combined with backfilling of exploited pits), manual extraction of the pay gravel and an owned mechanised concentration plant could be the optimal solution in many situations.

5.3.2 Local wage levels vs. mechanisation cost

Global experiences suggest that the optimum degree of mechanisation of artisanal mining depends on the relative cost of manual labour vis-à-vis the mechanised options. This can be seen as one reason for the successful mechanisation of artisanal diamond mining in South America (Brazil and Guyana) where (artisanal miners’) wages are relatively high compared to many African countries. The outlook for successful mechanisation projects tends to be higher in countries with a higher wage level.

5.3.3 Slow build or fast track

The full mechanisation of ASM can mean a quantum leap from artisanal operations, with their minimal human, physical and financial capital requirements, to operations similar to semi-industrial mining in almost no time. This type of “fast track” approach must usually be financed through debt and access to external funds, e.g. through a donor or government agency. However,

\(^{14}\) For example, in Sierra Leone a pump worth more than 1000US$ may be rented out for 2-3 US$/day, i.e. 0.2% of its value, while a washing plant worth between 3000 and 5000 US$ is rented out for 600 US$/day, i.e. 20% of its value; in Guyana the jig owner keeps a share of 55% of the total production; in Brazil in cases where exploitation of gravel is sub-contracted to earth moving companies 25% of the production is paid for these services – this underlines that regardless of investment costs the added value in the processing stage is much higher than in the exploitation of gravel; in Guinea it is general practice for mechanised small-scale miners to sub-contract earth moving while processing the gravel in a self-owned jig plant.
the high amounts of finance needed and the high risk of failure make this approach less attractive if not substantial investment is made in ensuring the conditions for success pre-exist.

In contrast to the “fast track” approach to mechanisation, Nick Hunter\(^{15}\) distinguishes the “slow build” approach, working from the basis that time and money are directly related. For example, a lack of funds slows development down. Yet, the evidence Hunter presents suggests that even with restricted funds artisanal miners can mechanise very successfully – and perhaps more successfully - in the slow lane. If artisanal miners mechanise on a step-by-step basis, they can capitalise on their gradually increasing returns more effectively by re-investing their proceeds into continual technical and mechanical improvements. Errors made along the way are low-cost and can thus contribute to a gradual learning process instead of jeopardising the whole process. In contrast to “fast track” mechanisation the “slow build” approach can therefore produce more sustainable results, based on a gradual process of trial and error which means miners can afford to make low-cost errors. It also facilitates deeper learning about more complex mining with regard to the operation of the new equipment, and, moreover, improvements in understanding and managing business finance, markets, buying and selling, costing and pricing, budgeting and planning, maintenance, security and safety etc. These important soft-skills do not come hand-in-hand with up-front investment (though they are pre-requisites for success), and are generated from operational experience.

Should this approach be taken, mechanisation would start with one aspect of the mining sequence (e.g. concentration), and then extend step-by-step to the mechanisation of other stages of production with a new step only being taken once the previous step has been completed and repaid. This is the optimal strategy for ensuring successful mechanisation.

### 5.4 The Potential for Local Manufacture

Successful mechanisation depends on the proximity of supply, manufacture, maintenance, service and repair as well as spare part supply for the equipment used. The country studies underline that in those countries where a certain technology is widespread there is an established local manufacture for these tools. Studies underline that the technical barriers for local or regional manufacture of mechanical tools are low\(^{16}\). High tech, such as hydraulic, electronic and power tools will generally be sourced from international companies.

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\(^{15}\) Hunter, 1993.

\(^{16}\) See Priester et al. Tools for Mining, GTZ, 1994

<table>
<thead>
<tr>
<th></th>
<th>Equipment for local manufacture</th>
<th>Equipment to be imported</th>
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<tbody>
<tr>
<td><strong>Pre-mech</strong></td>
<td>Screen/sieve, shovel/spade, bag, bucket, rope, winch, machete</td>
<td></td>
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<tr>
<td><strong>Non-motorised mech</strong></td>
<td>Hand jig, rocker</td>
<td></td>
</tr>
<tr>
<td><strong>Post-mech</strong></td>
<td>Gravel pump, suction dredge, dredge with airlift, trommel, jigs, feed hopper, sorting table, wheelbarrow</td>
<td>Generator, water pump (motor or electrical), back hoe, 4X4 truck, caterpillar, excavator, front end/back end loaders</td>
</tr>
</tbody>
</table>

Table 2 – Site of Manufacture for different types of Equipment used in mining.
6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The aim of this report has been to consider how and what type of mechanisation should be encouraged as a route to encouraging formalisation and increased productivity, as a basis for helping develop the artisanal diamond mining sector and affected communities. The variety of influencing factors – barriers or success factors – shows that any programme for mechanisation has to be built from the local, regional and national framework conditions. As these framework conditions differ considerably from country to country, a standardised mechanisation approach cannot be provided. Instead, the key results of the present study shall be used as a screening aid to identify and understand potential barriers or encouraging factors for mechanising alluvial artisanal diamond mining.

6.2 Key elements for a successful Mechanisation Programme

Key elements of a successful mechanisation programme would include appropriate access to finance, technical and managerial training advisory services and multi-stakeholder participation.

6.2.1 – Techniques for Encouraging Adoption and Diffusion of New Technologies

Before any diffusion, the technical-environmental measures selected must be tested and adapted jointly with the miners and approved by them. Only perfectly operational techniques should be presented to the miners.

Generally, low cost and simple technologies have much more diffusion potential than high cost and/or complicated methods.

Special attention should be paid to understanding how the mines and miners are organised, the socio-economic relations between miners, mine and land owners, diamond buyers, and financiers, and the cultural dimensions of production and trade (religion, customs, superstitions etc.). In many cases, these aspects and conditions are decisive for the outline of a successful dissemination programme. In contrast to technical issues, the social-economic-cultural aspects are much harder to change.

Successful technological developments have always started as “experiments” by individual companies that have tested an innovation with some success, and have gained economic advantages. Subsequently, these solutions have been copied and applied by neighbouring companies. “Models” can be enormously useful in diffusing knowledge. A “pilot mine” serves initially to experiment and optimise different technological alternatives, and subsequently becomes a model for others.

6.3 Proposals for Transversal Aid to the sector

6.3.1 – Solving legal impediments to mechanisation

Most of the mining codes in the countries assessed distinguish between artisanal operations and standard industrialised mining, with each category having quite different administrative procedures and requirements for formalisation. In most cases, however, a transition from one level into another is not foreseen, which poses a legal barrier to mechanisation. In addition to pilot measures for mechanisation, the DDI and the KP member country governments should develop legal mechanisms that allow for a gradual transition from artisanal to small-scale operations (addressing micro and small-scale enterprise development, licensing, land tenure and access to land).
6.3.2 – Guidance on best practice in AADM

Regardless of the nature of the pilot project or promotional measures for artisanal alluvial diamond mining, it is highly advisable to base this upon a concept of best practice. Mechanisation will change the mining processes applied and will lead to new risks related to the environment, compliance with national legal and fiscal requirements, occupational health & safety, and social well-being. Therefore, it is indispensable to have miners, officials, and other relevant stakeholders mutually agree on a clear concept of responsible mining, integrating environmental, social and economic principles. Both, governmental agencies as well as ASM operators, should commit themselves to this voluntary code aimed at responsible mining practices and sustainable development. These voluntary codes are an important element complementing the existing binding legal framework.

6.3.3 – Develop further understanding of barriers and success factors for formalisation

Given the importance of formalisation for the KP member countries as well as for the mechanisation of AADM further research into barriers and success factors for formalisation would be prudent to ensure that mechanisation would indeed be the optimal avenue for achieving this other goal. In a first step, it would be highly valuable to systematically assess the situation in other countries.

6.3.4 – Support formalisation of AADM by integrating the sector in the EITI process

In DRC, Ghana and Sierra Leone attempts are made to achieve certification under the Extractive Industries Transparency Initiative (EITI), which generally focuses on the formal mining sector. Nevertheless, an inclusion of the artisanal sector can contribute to an optimised dialogue between the key stakeholders, thereby enhancing the environment for formalisation.

6.4 Proposals for pilot projects

In order to support the mechanisation of AADM within the KP member countries pilot measures are desirable. Given the informality of the AADM sector, it is highly recommended that if programmes are to engage these informal actors, the proposed assistance should be given in a legally sheltered area. This means the governments would be part of the pilot project agreements and would guarantee that the pilot projects operate under a special regime on the understanding that they are being used to generate experiences for more successful sector development.

6.4.1 – Locally improve and adapt existing technologies for diamond concentration

As a consequence of the analysis of barriers and success factors for the technology transfer part of a pilot project, the techniques to be applied should not be selected only for their technical merits. Specifically, the socio-economic and socio-cultural backgrounds of the miners, and the local and regional infrastructure of the zone, should be integrated into the planning. This particularly includes the possibilities of local equipment manufacture. The majority of the equipment required for alluvial diamond gravel concentration should and can be produced in national, regional and local factories. The focus shall rather be on optimising a known technique and improve its operation than to introduce a new one. Especially for the African AADM countries the development and dissemination of an appropriate package of trommel, jig, pumps and energy generating system is required, as well as the development of simple dredges in combination with concentration equipment. Locally manufactured tools from Guyana could serve as masters for adaptation and local manufacture in the African target countries.
6.4.2 – Support to suppliers of locally manufactured equipment

Instead of supporting the mining sector directly, an alternative or complementary approach is to support the local equipment manufacturing and supply industry. Developing and upgrading local manufacturing industries so that they are best able to produce appropriate tools and equipment can do much to encourage local mechanisation. Specific actions include the provision of design masters of machinery for local adaptation, organisation of field tests, training for metal mechanics, quality control and promotion campaigns. This should be done with existing local or regional workshops. This approach uses the own interest of the companies to sell the product as a driving force for dissemination. Excellent experiences have also been made with the cooperation with technical colleges.

6.4.3 – Experiment with targeted mechanisation services

One country case study clearly indicates that hiring mechanised equipment becomes more expensive the closer one gets to the final product (diamonds). This suggests that in that country especially, an intervention aimed at mechanisation through self-owned equipment should tackle the processing stage first as the equipment for the other stages of the mining sequence can be hired more easily.

It is recommended to implement a pilot project supporting artisanal miners to combine mechanisation with own processing equipment by means of contracting commercial services to remove the overburden. This requires backing up the pilot project with advisory services (technical and operational planning, environmental considerations), management support (financial planning, tendering, contracting, monitoring and quality control), empowerment of the AADM organisation and skills development.

6.4.4 – Support cooperation and cohabitation of ASM with LSM/MSM enterprises

A large number of barriers can be overcome by promoting mechanisation of ASM through cooperation between artisanal miners and medium-to large-scale mining companies. Inspiration can be taken from a number of examples from both within the diamond sector (e.g. from the case studies from Guyana and DRC, from the Mwadui Community Diamond Partnership in Tanzania) and outside of it (e.g. Gold Fields “Live and Let Live” project in Ghana). Each project would have to be individually evaluated, but in general, the most efficient cooperation can be achieved when the larger, legal companies provide equipment and personnel for washing and concentrating the diamond bearing gravels and the artisanal miners concentrate on digging. The mining company would have the right to buy the stones produced by their equipment and mined in their concession.

It would be the task of the pilot project to provide appropriate master contracts between the mining partners based on existing best practice experiences. All involved parties have to play a role in this set-up: the government and local authorities, the legal medium/large scale mining company, the ASM and the traditional authorities. The pilot project should promote an attitude towards successful cooperation and provide the required assistance. If each of them adapts to a new way of doing things, win-win-projects can be created as well as new funding and support models, capacity building, and improved understanding between the large scale, legal operations and the ASM. The experiences of the pilot project should be disseminated as best practice examples.
There are examples from around the world where artisanal miners have brought themselves from the most basic of operations to running proper small- or even medium-scale mines in their countries of origin. These examples, however, are rare. Countries rarely create an enabling environment for artisanal miners and, instead of nurturing their indigenous sector through targeted efforts to professionalise their artisanal miners into proper corporate miners, they prefer to rather facilitate investment and mine development by foreign actors. This may be cheaper and easier, and bringing more immediate gains, especially for the state. But emphasising a nation’s artisanal sector can bring more sustainable development and larger gains in the longer-term for the people and eventually the state (Tibbett 2009). Helping artisanal miners mechanise their operations as part of an integrated approach to formalisation could help create a culture of professionalisation, which would nurture more sustainable local and national development. As this study has shown, mechanisation (or formalisation) alone, however, cannot achieve these development gains. An integrated approach is required, incorporating investment in the addressing of other barriers to development in ASM.

Although facilitating investment and mine development by foreign actors may be cheaper, easier and brings more immediate gains for the state, advancing the nation’s artisanal sector can bring more sustainable development and large gains in the longer-term for the people, and eventually the state.


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