Mechanisation of Alluvial Artisanal Diamond Mining

BARRIERS AND SUCCESS FACTORS

Michael Priester & Geert Trappeniers

DDI WORKSHOP ON THE MECHANIZATION OF ARTISANAL DIAMOND MINING

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Countries with projects studied as part of the DDI assessment implementation projects of Projekt-Consult GmbH with relevant lessons for mechanisation of ASM.
Authors of the study

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Outline

- Current mining practices as a starting point for mechanisation
- Key factors influencing the mechanisation process
- Socio-economic and environmental impacts of mechanisation
- Project experiences in mechanisation and introduction of new technologies
- Recommendations
Current mining practices as a starting point for mechanisation

Actors, type of AADM, mining techniques, nature of the deposit, hydrological conditions, mechanisation approaches
The actors

- Labourers (diggers, gravel transporters, washers)
- Gang leaders (Group chiefs)
- Site chiefs (mine managers)
- Title holders
- Land owners
- Buyers (intermediaries, exporters)
- Financiers

- 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
Different types of AADM

- Rush AADM
- Temporary (emergency) AADM
- Isolated AADM
- Seasonal AADM
- **Traditional all year round AADM**

- *If mining is his/her principal livelihood the miner is more likely to embrace mechanisation*
Mining techniques – process sequence of allivial diamond mining (1)

- Deposit
  - Situated below or near the ground and surface water level
  - Deviation of the river, drying up of parts of the river bed, pumping off the ground and surface water, construction of dams, drainages or shafts

- Exploitation of diamond placers
  - Situated above the ground and surface water level
  - Soil and overburden removal: front shovel loader, backhoe, trucks, shovels and wheel barrows

- Exploitation in the river (wet exploitation): Pirogues, suction dredge, drag line

- Exploitation in artificial lakes (wet exploitation): Suction dredge, drag line, backhoe for alimentation of a floating concentration plant

- Hydraulic exploitation: “Monitoring” or gravel pumping

- Dry exploitation: Front shovel loader, backhoe, trucks, shovels and wheel barrows
Mining techniques – process sequence of allivial diamond mining (2)

Transport of rough to the concentration plant

Slightly consolidated material
- Disintegration
- Washing sluice
- Sizing Trommel

Loose material
- Classification
- Feed hopper
- Fixed screen
- Shaking screen
- Sizing trommel

Concentration of diamond placers

Backfill and renaturation:
- Front shovel loader
- Backhoe
- Trucks
- Shovels
- Wheel barrows

Gravity Sorting
- Handpicking
- Sluicing
- Spiral concentrator
- Heavy media separation
- Panning
- Hand jig
- Mechanized jig
- Diamond pan

Sorting using the surface properties
- Grease table

Optical Sorting with pneumatic separation

Refining: Handpicking

Final
Mining techniques for different geological and geographical situations

- **Location of Deposit**
  - Riverbed
  - Riverbank
  - Surface alluvial

- **Overburden / substrate**
  - Water
  - Water & Soil
  - Soil (<1m)
  - Soil / sedimentary deposits (1 – 30m typically)

- **Technical Approach**
  - Diving
  - Dredging
  - River Diversion
  - River Diversion Hosing
  - Digging
  - Opencast Top-grading pits
  - Opencast Top-grading pits Underground galleries
<table>
<thead>
<tr>
<th>Deposit Type</th>
<th>Manual artisanal mining process</th>
<th>Mechanised artisanal mining process</th>
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</table>
| Alluvial, eluvial or colluvial deposit on dry land | **Open pits**  
Equipment & techniques used:  
• Picks and spades for digging and loading minerals  
• Buckets and bags for transportation  
• Small pumps for evacuating water  
• Sieves for separating gravel  
• Hand-picking for selecting minerals  
Most productive and least dangerous method  
Risks: rock falls, accidents with picks and spades  
**Features for ASM:** minimal investment required, operation in small gangs possible, higher productivity in deposits with shallow overburden, continuous operation possible | Similar exploitation process:  
• Removal of overburden  
• Exploitation of gravel by machines  
• Mechanised transport  
• Concentration in mechanised washing plants  
Require larger areas to be financially viable  
Higher recovery of the deposit  
Systematic mining processes with better possibilities for backfilling, rehabilitation  
If enough water is available high (water) pressure monitoring and hydraulic transport is an option |
Artisanal operation on dry land
Mechanized operation on dry land
## Potential for manual and mechanised artisanal mining for different deposit types

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<td>Palaeo-placer, old terraces, placer with thick coverage of sterile overburden on dry land</td>
<td><strong>Underground galleries:</strong> Artisanal miners dig circular holes of approximately 90 centimeters diameter and typically up to 35 meters deep. The gravel is charged in bags or buckets at the bottom of the gallery, then evacuated with a winch or pulley system. This method presents many dangers such as the lack of oxygen in the gallery, and the risk of rock falls and tunnel collapse. <strong>Features for ASM:</strong> 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</td>
<td>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.</td>
</tr>
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Digging underground shafts
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<td>Alluvial deposits in rivers</td>
<td><strong>Diving:</strong> Artisanal miners dive in rivers and extract the gravel in buckets or bags. This is hauled to a pirogue. After prospection, the miners pan manually separate gravel from minerals found at the bottom of the river. <strong>Features for ASM:</strong> 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)</td>
<td>Dredging with suction dredges or elevator dredges; use of mechanical breathing apparatus and wet-suits</td>
</tr>
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Pirogues with diving diamond diggers in a river
River dredge
## Potential for manual and mechanised artisanal mining for different deposit types

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<td>Alluvial, deposits in rivers</td>
<td><strong>Dykes:</strong> 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. <strong>Features for ASM:</strong> 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)</td>
<td>Mechanised operations require a different mining process with dredging in the river similar to the above mentioned solution.</td>
</tr>
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Dykes of artisanal diamond diggers in CAR
Dykes of artisanal diamond diggers in CAR
Mechanisation approaches

- Three starting points:
  1. Removing the overburden
  2. Extracting and transporting the pay gravel
  3. Diamond concentration
Mechanisation approaches

Stage of Process
- Removing overburden
- Extracting the gravel
- Concentrating the gravel

Mechanisation Options
- Specific mechanisation opportunities

Impacts
- Impacts on specific people and environments
  - WOMEN
  - CHILDREN
  - ELDERLY
  - COMMUNITIES
  - INDIGENOUS PEOPLES etc.
  - DIVERS
  - DIGGERS
  - TRANSPORTERS
  - PANNERS etc.
  - RIVERS/STREAMS/LAKES
  - GRASSLAND/FOREST/COASTAL ECOSYSTEMS
  - AIR/WATER QUALITY etc.

Vulnerable groups
- Roles
- Environments
Mechanising the removal of overburden

- Productivity increase
- Liberation of diggers from arduous work of overburden removal
- Thus more time for gravel exploitation and/or diamond washing
- For cost-effectiveness the following is required:
  - exact knowledge of the depth and geometry of the upper limit of the diamond bearing gravel layer
  - new systems of management
  - planning for systematic exploitation and combined backfill
Mechanising the extraction and transportation of pay gravel

- Can reduce level of manual digging needed
- Would require reorganisation of the pit
- Machines rarely used at this stage because
  - machines applied for extracting the gravel do not work well on uneven ground
  - high costs associated with fuel and wear and tear
- Different option for deposits on dry land: hydraulic monitoring (but: high operational cost)
- Mechanisation of gravel exploitation in riverine deposits by river dredges
Mechanising the diamond concentration

- Trommel or shaking sieve in combination with a modern jig can replace manual labour
- Higher recovery rate
- Requires reorganisation of miners
Mechanized Jigs

Jigs for diamond concentration, Bafi, Sierra Leone
The upper technological end

A mobile diamond concentration plant in Mwadui, Tanzania
Key factors influencing the mechanisation process

Drivers, barriers and success factors: enabling environment, socio-economic factors, technological factors, geographical factors, programmatic design factors
Drivers for mechanisation

- **Economic**
  - higher returns due to the faster exploitation,
  - less effort,
  - higher recovery,
  - security and safety gain

- **Socio-cultural**
  - higher social reputation and social status

- **Environmental**
  - overcome seasonal limitations to artisanal mining,
  - get access to deeper deposits
Enabling environment

- Political order
- Administrative requirements for formalisation
- Legal framework of licensing
- Capacity and will of local or national authorities to enforce the law
- Access to land and land rights (security of rights)
- Access to finance
- Access to existing support measures
- Existence of formal companies with a positive attitude towards artisanal miners
Socio-economic factors

- Legal status of the ASM operation
- Internal organisation of the artisanal miners and their socio-economic dependencies
- Role of ASM within the individual or household livelihood strategy
- Level of mobility of ASM
- The trade chain
- Cost of labour
- Real and perceived benefits or losses for key stakeholders
- General education and knowledge levels
- Customs and traditions ..
Technological factors

- Access to appropriate technology
- Trust in the new technology
- Knowledge about the parameters of the mining operation
- Level of training and know-how
- Security considerations ..
Geographical factors

- Geological, geomorphologic and hydraulic characteristics of the deposit
- Remoteness of the ASM operation ..
Programmatic design factors

- Community should be co-owner as well as beneficiary of project
The relation between the factors
Socio-economic and environmental impacts of mechanisation
Positive socio-economic impacts

- For miners
  - Improvement in the **working conditions** of people involved in mining (including women)
  - **Minimisation of child labour** in mining due to higher skilled labour
  - **Decrease in mining-related accidents** due to better mine planning and the substitution of underground mining through open cast operations
  - Greatly **increased technical skills** among young community members
  - **Diversification and improvement of livelihood strategies**
  - **Increased human capital** among artisanal miners is generated through training programmes and new equipment
  - Mechanisation can have a **positive effect on OSH**
Positive socio-economic impacts

- For mining communities
  - Sustainable increase in the income of rural community members
  - Improvement in the provision of public facilities and services in participating communities (incl. education, health, power, local roads)
  - Decrease in intra and inter community tensions and conflict through strengthened mechanisms of dialogue, negotiation and consensus-building within participating communities, where mechanisation programmes attempt an integrated approach
  - Increased social capital in participating communities as a consequence of all the above ..
Positive socio-economic impacts

AADM community members during interviews in Mwadui, Tanzania discussing their development
Positive environmental impacts

- Reducing the long term footprint of mining:
  - Higher recovery of the deposit
  - This improves the case for reclamation and rehabilitation, 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
  - Making reclamation easier
  - Introduction of environmental management systems
Adverse socio-economic impacts

- Increased seriousness of accidents where machines are not properly used or maintained
- Risk of loosing machinery and collaterals from credits in the case of having lower revenues than expected with the mechanised operation
- Loss of jobs due to the replacement of muscular with mechanical power
- Masculinisation of the workforce and marginalisation of women
- Increased conflict with local communities and authorities i.e. over the environmental impacts of mechanised mining...
Adverse environmental impacts

Example from alluvial artisanal diamond mining in Sierra Leone

On huge surfaces
Adverse environmental impacts

- Increased environmental impact unless the mechanisation is accompanied by sensitisation measures
- Greater areas of land can be exploited in a set time-frame
- Increased use of fuel increases the risk and likelihood of fuel spillage, leakage and pollution, and increases air pollution
- Lack of options for disposing broken or worn-out equipment (littering the landscape, creating a hazard for people and animals)
- Higher rates of production mean greater volumes of waste materials
- Increased downstream turbidity of rivers esp. in the case of hydraulicking (monitoring), of dredges as well as the use of larger washing plants
Experiences regarding the **financing** of mechanisation, the cost-effectiveness, and the potential for local manufacture of machines
Financing of mechanisation

- Traditional bank loans are usually unaccessible for artisanal miners. Reasons are:
  - Alluvial ASM are a mobile target!!!
  - Lack of collateral
  - Lack of management capabilities of artisanal miners
  - Lack of banking culture
  - Bankers have no idea of mining ..
Financing of mechanisation

Alternative sources of finance include:

- small and medium scale companies
- machine owners and equipment sellers
- local diamond buyers
- ‘investors’
Financing of mechanisation

- The Brazilian example: payment by share of production
  - A “backer” (financer) pays the miner a minimum wage and in return receives 50% of the miner’s production.
  - 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.
  - Mechanisation is possible without having large amounts of upfront capital.
  - The risk is spread among several people.
- But: reasonable level of social cohesion and trust necessary (production must be declared honestly)
Financing of mechanisation – Lessons from past projects

- High interest rates discourage miners from borrowing for *investments* and limit them instead to borrowing for liquidity management (*bridge-funding*)

- Loan *guarantee*: feasibility studies are usually beyond the capacity of artisanal miners

- Positive experiences have been made in stable communities with *mutual guarantee funds*

- Funding facilities can be more successful when *based on existing, local financing / lending systems*

- Funding facilities tend to be more successful when *fully managed by local organisations* which are embedded in the regional economic and cultural environment ..
Financing of mechanisation – Lessons from past projects

- A **minimum understanding of mining, geological risk and cost structures in the credit institution** is essential for them to be able to evaluate proposals.

- **Matched funding** can up success, i.e. where the investor him/herself makes a considerable financial contribution.

- It is important to **combine credit with savings** in order to generate a banking culture.

- Positive examples are those where the **credit facilitator steps into the risk** of mining; e.g. FONEM, Bolivia.
Cotapata mine, Bolivia, an example for successful mechanisation

In 1993 the area has been declared national park. The arrow marks the site of the mine of Cotapata where a cooperative of about 50 members mines gold ores.
Final stage of mechanisation in Cotapata

Results of the mechanisation:
• recovery and grade of concentrates elevated
• responsible mining practice
• gold containing pyrites separated as by-product
• rejects piled up
• process water treated before discharge to river.

The total cost for the equipment of the concentration plant was in a range of 36,000 US$. This was covered by co-financing between the cooperative and the Swiss funded MEDMIN project and had been realised in two separate stages.
The cost-effectiveness of different types and levels of mechanisation

- Cost of buying vs. cost of contracting/renting equipment
  - Contractor mining is common in Africa for earth moving services
  - Substantial differences in buying and contracting costs between different machines: relative prices for rented or leased equipment increase as one moves along the process towards the finished product

→ Optimal strategy:
  - Contractor mining for overburden removal and backfilling
  - Manual extraction of pay gravel
  - Mechanised concentration plant owned by miners
The cost-effectiveness of different types and levels of mechanisation

- Local wage levels vs. mechanisation cost
  - Optimum degree of mechanisation of artisanal mining depends on the relative cost of manual labour vis-à-vis the mechanised options
  - Higher degree of mechanisation in countries with higher wage levels (South America)
The cost-effectiveness of different types and levels of mechanisation

- Slow build vs. Fast track
  - Step-by-step mechanisation
  - Reinvesting increasing profits in mechanisation of operation
  - Learning while growing (trial and error process)
  - Better chances for sustainable success than large external investment and mechanising everything at once.
## Potential for local manufacture of equipment

<table>
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<tr>
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<th>Equipment for local manufacture</th>
<th>Equipment to be imported</th>
</tr>
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<td><strong>Pre-mech</strong></td>
<td>Screen/sieve, shovel/spade, bag, bucket, rope,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>winch, machete</td>
<td></td>
</tr>
<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,</td>
<td>Generator, water pump (motor or electrical),</td>
</tr>
<tr>
<td></td>
<td>trommel, jigs, feed hopper, sorting table,</td>
<td>backhoe, 4X4 truck, caterpillar,</td>
</tr>
<tr>
<td></td>
<td>wheelbarrow</td>
<td>excavator, front end/back end loaders</td>
</tr>
</tbody>
</table>
Recommendations
Key elements of a successful mechanisation project

- Ensure a stable legal situation
- Access to finance
- Technical and managerial training advisory services
- Multi-stakeholder participation
- Technology should be fully operational and tested and adapted jointly with the miners
- Low cost simple technologies have greater potential
- The socio-economic and cultural factors influencing mechanisation should be well understood
- Pilot mines can be used to experiment and later serve as models..
Proposals for Transversal Aid to the sector

- Solving legal impediments to mechanisation:
  - Facilitating the gradual transition from artisanal to mechanised small-scale operations

- Providing best practice guidance for responsible mining:
  - Mechanisation comes along with new risks and increased socio-environmental impacts
  - To address these all relevant stakeholders should commit to a code of responsible mining, which complements the legal framework

- Developing further understanding of barriers and success factors for formalisation

- Supporting formalisation of AADM by integrating the sector in the EITI process
Pilot project proposals

- Locally improve and adapt existing technologies for diamond concentration
- Support to suppliers of locally manufactured equipment
- Support AADM with targeted mechanisation services (support mechanisation combining the procurement of self-owned equipment for the processing stage and contracting machinery/services for the overburden removal)
- Support cooperation and cohabitation of ASM with LSM/MSM enterprises
Artisan - Company cooperation

- Artisan miners
- Middle men
- Local chiefs
- Local communities

Claim the right to work “their” land

- Company shareholders
- Board members
- Management

Claim the exclusive right to mine the concession
Current situation

- Conflicting interests leading to:
  - Uncontrolled mining & trading
  - Artisans being removed by army, police, security
  - Security issues
  - Destabilized local situation
  - Increased spending on security
Geological situation

- Calonda gravels under high overburden
- Related secondary hill-slope deposits with limited overburden
- River flats deposits, sometimes high grade, sometimes very dispersed patches
- Rather flat plateaus, cut by small steep valleys
COOPERATION

- cooperation has to create a win-win situation for both parties
- mine management needs to convince shareholders
- artisan miner representatives & local authorities have to convince the artisans
- Advantages: improved security, improved local situation & economy, increasing income for artisans & company
Technical evaluation

- Artisan miners efficiently mine:
  - Very high overburden areas
  - Steep or difficult access areas
  - Small dispersed patches of gravel

- Bottleneck: Artisan washing and concentrating methods are not efficient
Practical cooperation

- Allow artisan mining in areas of high overburden, difficult access, ...
- Other areas are reserved for the company
- Company provides small, simple processing equipment: washing trommels & jigs
- Equipment is run by company personnel
- Artisans are present during processing
- Company charges small processing fee to avoid sterile gravel being brought in.
- Company buys processed goods at local rate
- Alternative: gravel sharing
Additional considerations

- Paying for processed diamonds with locally purchased essential goods leads to improved local economy.
- Company representatives will have to keep track of artisan operations at all times.
- Company can assist with transport of gravel from mine to processing site,
- by improving safety of mining process,
- by improving access roads, sanitary situation, security in artisan camps.
- Levelling and rehabilitating mined out areas helps local agriculture.
Need for a legal framework

- Registration of artisan miners
- Artisans can not be considered as company personnel
- Company can not be held responsible in case of mining accidents
- Purchasing of diamonds from artisan gravel processing needs to be covered legally
Diamond diggers in a mining venture with mechanically removed overburden, Ghana
Thank you!!

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