Journal of Environments
Vol. 6, No. 1, 14-20, 2020
ISSN(E)2313-660X
DOI: 10.20448/journal.505.2020.61.14.20

The Effect of Mechanization on Safety and Productivity of a Gold Mine

A.K. Banson

University of Mines and Technology, Tarkwa, Ghana.
Email: alex.banson@gmail.com Tel: +233204330222

Abstract

New resource determinations enable gold mines to change from the conventional system of mining and introduce mechanized mining methods. This decision could however be plagued with problems. It is necessary to review mechanization to determine its impact. In this study safety, gold production, productivity, manpower, maintenance and equipment cost data was collected and analyzed along with questionnaire and interviews from a mine to determine its performance before and after mechanization. From the study, mechanization reduced mining grade cut-off by 86%, increased gold production per annum by 94%, has increased tonnage productivity per man-month by 564%, improved the skill levels of workers but reduced manpower by 53% and has potential to creating labour unrest. It has helped reduce Loss Time Injury Frequency Rate by 1160%, has helped reduce accidents by 94%, but has potential to increase fatality on a mine. Mechanization is also capital intensive with high maintenance cost, causes the inability of mines to sustain production levels, rapidly exhausts ore reserves, causes grade control problem associated with dilution of the ore hence increasing operating cost, workers are exposed to long term health risk, and there is high incidence of crime.

Keywords: Mechanization safety productivity gold mine.

Citation | A.K. Banson (2020). The Effect of Mechanization on Safety and Productivity of a Gold Mine. Journal of Environments, 6(1): 14-20.
History:
Received: 6 July 2020
Revised: 10 August 2020
Accepted: 14 August 2020
Published: 24 September 2020

Publisher: Asian Online Journal Publishing Group

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.
Transparency: The author confirms that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study follows all ethical practices during writing.

Contents

Contribution of this paper to the literature

This paper makes significant contribution to the advantages and challenges faced in mechanization of gold mining operations. It offers recommendation to reduce the negative impact of mechanization of gold mining operations. This paper has established that mechanization of a gold mine has significant benefits in terms of productivity. However, more care should be taken to reduce incidents and fatality on the mine.

1. Introduction

New resource determinations enable gold mines to change from the conventional system of mining and introduce mechanized mining methods (Bilim & Kekeç, 2016; Laflamme, 2002; Miller, 2009; Nong, 2010; Nong & Musingwini, 2011; Vogt & Hattingh, 2016).

Most gold mining companies re-evaluate their ore resources at lower cut-off grades, if massive mining methodology or mechanization could reduce the cost of mining and improve productivity (Paraszczak, Gustafson, & Schunnesson, 2015). With current improvement in technology, new resource determination can enable mines to change from the conventional system of mining and introduce the mechanized mining method to mine more ore and increase productivity (Boulter & Hall, 2015; Castro, Riquelme, Widzyk-Capehart, Hekmat, & Baraqui, 2015; Mundry, Gajetzki, & Hoseinie, 2015). The change to mechanization can be technically, socially and economically challenging (Ghodrati, Hadi Hoseinie, & Garmabaki, 2015; Willis, Dixon, Cox, & Pooley, 2004). It is therefore necessary to carry out a review of changes to mechanization to determine whether mines and their stakeholders are better or worse off with the change. It is also necessary to determine ways to improve the system to make it more efficient and profitable? This is what this study seeks to address.

2. Field Studies

The study was carried out on a mine in Ghana. The mechanization operations of the mine started at the northern section whilst most of the conventional systems were still in use at the southern section. The information for this study was collected from the loss control, planned maintenance, human resource, technical and engineering section of a mine. Data was collected with the aim to determine the effect of the mechanization programme on the mine, workers and residents of the community.

2.1. Manpower

Table 1 shows the average number of workers who were employed at the mine in the year 2013 when the company was changing from conventional to mechanized mining. Table 2 shows the average number of workers employed in the year 2019.

Table-1. Average Manpower in 2013.

Date	Staff at Work	Staff on Leave	Staff Absent	Staff on Day-off	Staff on Sick Leave	Staff Strength
January	1954	257	7	115	133	2466
February	1856	271	18	216	107	2468
March	1874	266	17	208	103	2468
April	1931	265	10	133	128	2467
May	1985	226	13	88	156	2467
June	1945	221	13	133	155	2467
July	1978	217	10	124	140	2468
August	1885	306	7	146	124	2468
September	1838	305	20	203	100	2466
October	1901	304	12	140	109	2466
November	1963	278	13	102	109	2466
December	1927	270	16	134	119	2466
Average	1920	265	13	145	124	2467

Table-2. Average Manpower in 2019.

Month	Staff at Work	Staff on Leave	Staff Absent	Staff on Day-off	Staff on Sick Leave	Staff Strength
January	1270	139	46	83	72	1609
February	1292	130	41	72	73	1608
March	1302	125	28	65	89	1608
April	1264	124	42	72	107	1608
May	1276	110	38	108	79	1612
June	1292	108	25	100	85	1610
July	1322	106	24	80	78	1610
August	1308	102	26	86	88	1610
September	1294	128	22	82	85	1610
October	1218	128	23	170	71	1610
November	1229	124	25	166	67	1610
December	1284	119	34	107	66	1609
Average	1279	120	31	100	80	1609

2.2. Safety Records of the Mine

Table 3 shows the various causes of accidents on the mine and Figure 1 and Figure 2 show the causes of incidents for years 2013 and 2019 respectively.

Table-3. Causes of Accidents on the Mine.

Accident Type	Year 2013		Year 2019	
	Average Monthly	Year Total	Average Monthly	Year Total
Electric shock	0	0	0	1
Explosive	0	1	0	0
Fall of ground	1	13	0	2
Falling material	3	34	0	2
Handling	2	11	0	1
Machinery	1	17	3	35
Slip fall	1	8	0	4
Trucking	2	14	1	7
Other	0	3	0	0
Total	10	101	4	52

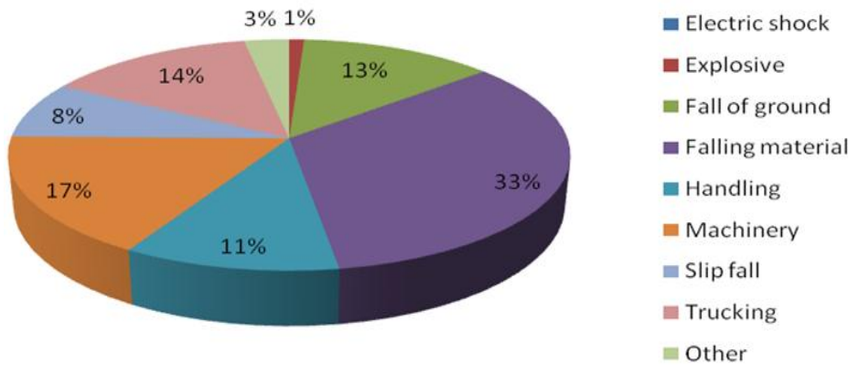

Figure-1. Causes of accident for year 2013.

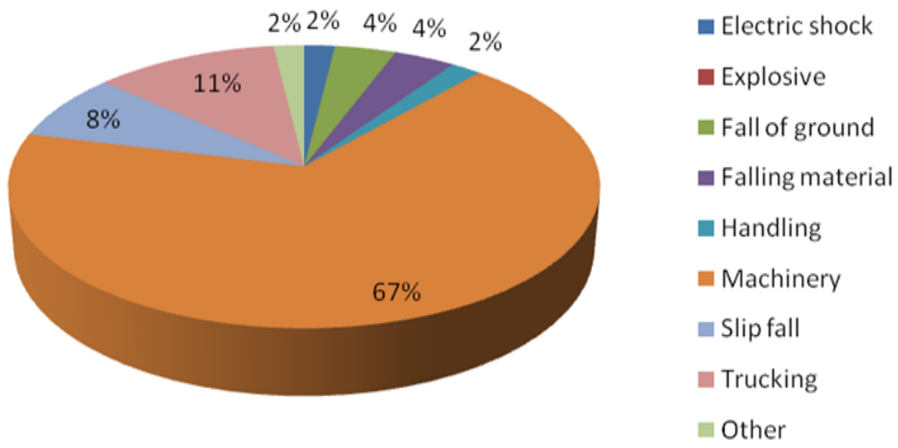

Figure-2. Causes of accidents for year 2019.

Table 4 presents the injuries that occur in the mine and shows that arms, legs and multiple injuries which could be a combination of any of the injuries are prominent just before mechanization. It also shows the total number of incidents has reduced. However, the severity of the incidents has increased after mechanization. Figure 3 and Figure 4 classify the injuries in 2013 and 2019 respectively. It can be observed that prior to mechanization injuries were mainly leg, arms and multiple. However, after mechanization, the injuries are mainly multiple. This shows the seriousness of results of accidents from mechanization.

Table-4. Classification of injuries.

Injury Type	Year 2013		Year 2019	
	Average Monthly	Year Total	Average Monthly	Year Total
Arm	2	19	1	8
Eyes	0	1	0	1
Feet	1	10	0	2
Hands	1	9	0	2
Head	0	1	0	1
Legs	2	22	1	9
Trunk	1	11	0	1
Multiple	2	21	2	18
Other	0	1	0	7
Total	9	95	4	49

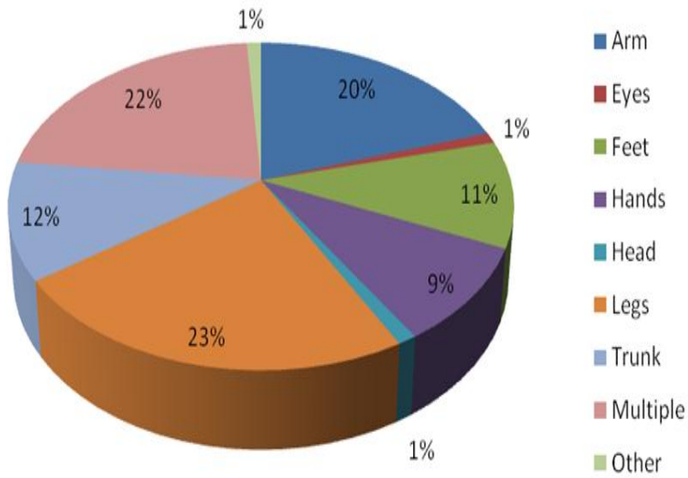

Figure-3. Classification of injuries (2013).

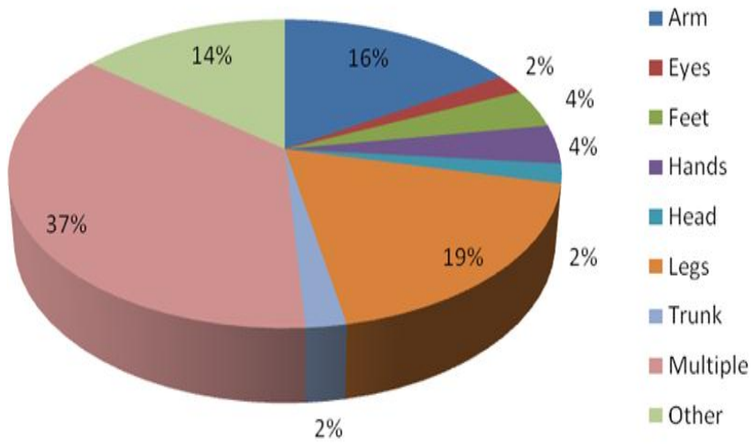

Figure-4. Classification of injuries (2019).

Figure 5 is a graph showing the Loss Time Injury Frequency Rate (LTIFR) from October 2009 to December 2019 which is from the commissioning of the mine (conventional system) to a fully mechanized operation. Figure 6 shows the LTIFR for April 2016 to December 2019 which is the full mechanization era. Figure 7 shows the LTIFR from the beginning of mechanization to the fully mechanized operation.

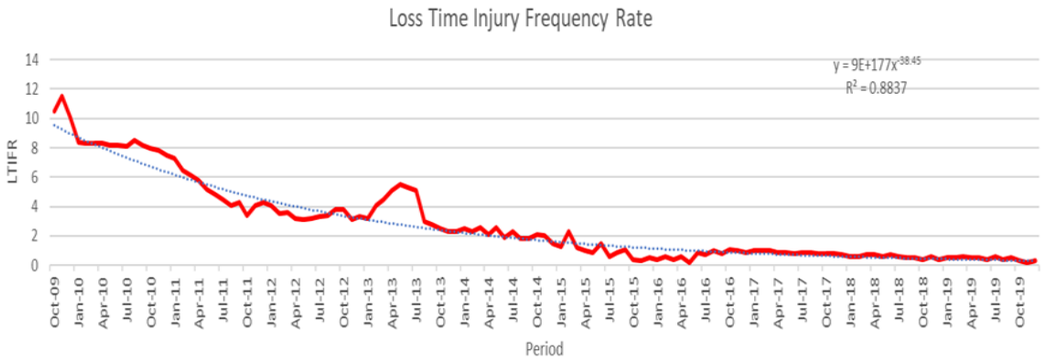

Figure-5. Graph of lost time injury frequency rate from 2009 to 2019.

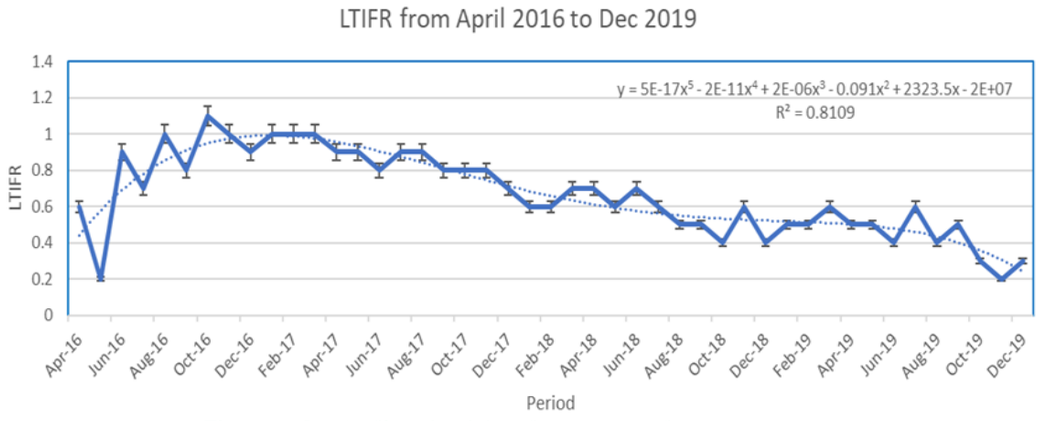

Figure-6. Graph of lost time injury frequency rate from 2016 to 2019.

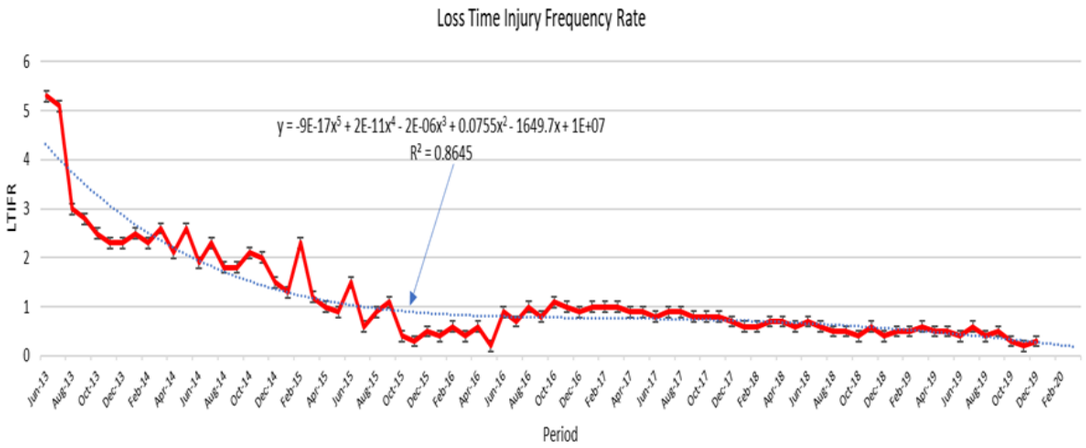

Figure-7. Graph of lost time injury frequency rate from 2013 to 2019.

2.3. Production and Productivity

Information for the period of investigation was obtained from the mine and collated to obtain the following:

- Average mill grade ore tonnage produced and average manpower.
- Production by ounces.
- Productivity in terms of ounces or tonnage per man hour.

2.3.1. Average Mill (Ore) Grade and Tonnage

Figure 8 shows a graph of Ore Grade and Ore Tonnage achieved and corresponding manpower from 2010 to 2019. The graph also shows the projected values from 2020 to 2023 when the mine is likely to shut down if new ore body is not found.

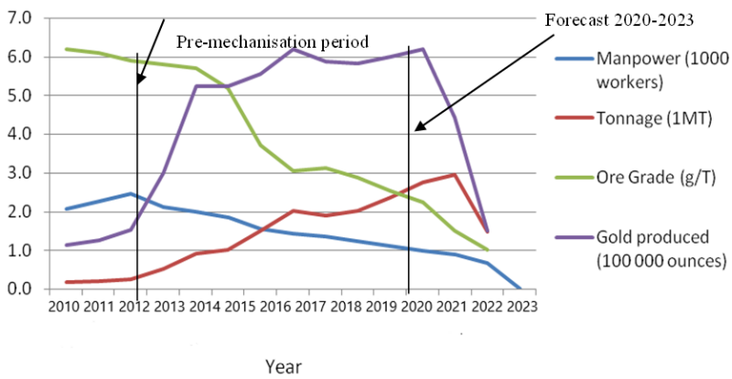

Figure-8. Actual and forecast parameters with production (2013 to 2023).

2.3.2. Productivity

The mine productivity considered here is the tonnage produced per man-month and the ounces produced per man-month. Figure 9 shows the productivity of the company from the year 2010 to year 2019 and a forecast from 2020 to 2023. This shows the gradual increase in the productivity of the mine as it migrates slowly from the conventional system to the present-day mechanized system of operations. However, after year 2021, ounce productivity will begin to drop as a result of inability of the workforce to mine more ore to cope with the reduction in ore grade.

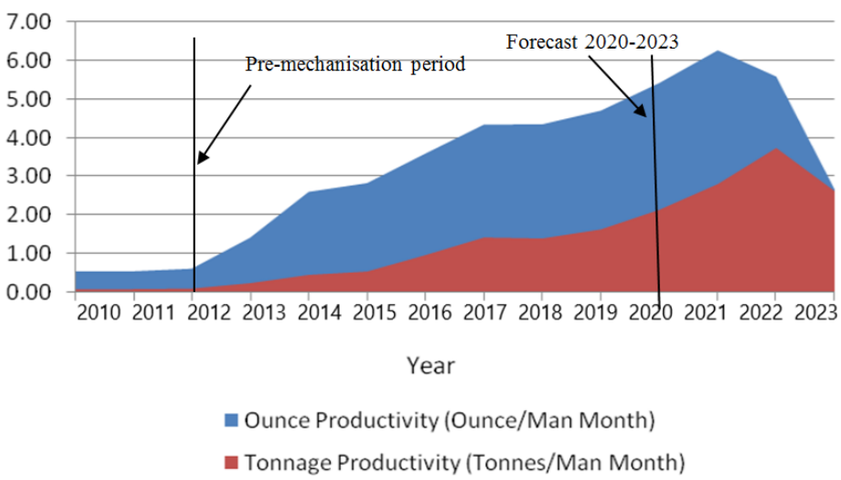

Figure-9. Mine productivity graph for 2010 to 2023.

2.4. Questionnaire Administration

This study includes distribution of questionnaire to workers and residents of the community to sample their views on the current mechanization programme. Out of one hundred questionnaires sent out to the various sections

of the mine only sixty-five was returned. However, twenty-two of them were interviewed to make up for their inability to provide written answers. The responses obtained from interview and questionnaire helped in knowing some of the feelings of the workers about the mechanization programme.

3. Analysis of Data

3.1. Analysis of Labour Strength

Comparing information on Table 1 and Table 2 indicates how the labour strength has been reduced by 53% from an average of 2467 in 2010 to 1610 in 2019. This however implies there is a corresponding increase in unemployment rate in the community or country.

3.2. Analysis of Safety Information

It can be observed from Figure 5 to Figure 7 that the lost time injury frequency rate has decreased tremendously from the conventional era through the pre-mechanization era to the present full mechanization era. With the conventional system some of the numerous unskilled workers were inadequately aware of simple safety measures and were subjected to various accidents and even fatalities in the cases of heavy ground fall. Some of these accidents were also attributed to the mining systems in use. The improvement in the safety record should not only be directly attributed to mechanization. However, it can be noted that mechanization requires personnel with higher levels of skill and education. This can relate to higher awareness of safety. Improvement in safety can also be attributed to increases in safety education. This was not investigated. It could also be assumed that that although there is a reduction in injury frequency some peaks in the graph need explanation. The trend from 2013 to early 2017 indicates that more must be done to make mechanization a safer system. It can be seen from Figure 2 that there has to be improvement in safety of machine usage. Further investigation revealed that majority of accidents was on the night shift. This implies safety can be seriously improved if majority of the machine movement is done during the day.

3.3. Analysis of Production and Productivity Records

It can be observed from Figure 6 that when the conventional system was fully in place lower tonnages of high-grade ore (selective mining) was mined. The situation however changed with the advent of mechanization to the point where seven times the production of 2013 was mined at grades below 2.2 g/tonne in 2019. Ounce and tonnage productivity at 2013 were 1.43 and 0.25 respectively. The ounce and tonnage productivity increased in 2019 to 4.72 and 1.63 respectively with a corresponding percentage increase of 231% and 564%. It can therefore be observed that the mechanized system is more productive than the conventional system.

3.4. Achievements and Problems Associated with the Mechanization Project

From interviews and questionnaire administered, the following achievements were found to be associated with the mechanization programme:

1) Workers feel safe and confident when working. Workers also feel less exposed to danger.
2) The mine can be expanded to mine more ore blocks.
3) Improved skill level of the general work force.

Some problems were found to be associated with this mechanization system. The problems are:

1) Some workers are exposed to dangerous nitrous/carbon fumes from mechanized equipment.
2) Retrenched workers join illegal mining "galamsey" operators to apply their acquired skill in illegal mining. They are even able to dig addits to intersect orebodies of mining companies.
3) Some unemployed residents of the community rush to the face after blasting to steal high grade ore before the dust settles. Such an action endangers their life. Such activities also reduce revenue of the mine.
4) The mine is unable to sustain production levels with mechanization.
5) There is fast exhaustion of the mine ore reserves.
6) According to employees, mechanization has problems associated with grade control/dilution.

4. Summary of Results

The study and findings can be summarized as follows:

1. Mechanization has reduced labour strength by 53% and has a likelihood of creating labour unrest in a mine.
2. Mechanization has reduced Loss Time Injury Frequency Rate by 1160%.
3. Mechanization has helped reduced accidents by 94%.
4. Cause of accidents during mechanization is mainly due to machinery working at night.
5. Mechanization has made it possible to mine low grade ore from a high of 6.2 g/T to 2.89g/T and an estimated low of 1.02 g/T.
6. Mechanization has increased ore production per annum by 289%.
7. Mechanization has increased gold production by 94%.
8. Mechanization has increased tonnage productivity from 0.62 tonnes / man month to 3.94 tonnes /man month.
9. Mechanization improves the skill levels of general workforce.
10. Mechanization causes the inability of mines to sustain their production levels.
11. Mechanization exhausts ore reserves rapidly.
12. Mechanization causes grade control problem associated with dilution of the ore hence increasing operating cost.
13. Some workers are exposed to long term risk such as intense heat, tuberculosis, silicosis, and dangerous nitrous/carbon fumes from mechanization.

5. Conclusion

It can be concluded from the study that the mine can increase productivity with a possible decrease in operating cost and a possible increase in profit at the expense of the employment situation in the community. Reduction in farming activity as a direct result of mechanization has also increased unemployment in the community. The increase in unemployment in the mining community has triggered the increase in illegal mining and the potential to increase criminal activities in the community. Mechanization has however improved the occupational health and safety status of most workers and worsened that of some few workers on the mine.

Irrespective of the challenges of mechanization, it is concluded that mechanization has a positive impact on performance of gold mining projects and can benefit the community if managed properly. However, it will be difficult to say that mechanization has helped all stakeholders of the mining community.

6. Recommendations

The following should be considered by mining companies who have plans to mechanize their existing operation:

i. Employees should be given more training on safety and health issues.
ii. Mining companies should collaborate with academic institutions to find better and safer ways in mechanization.
iii. There is the risk of rapid collapse of the mining industry or economic activity in a community when the ore is depleted by mechanisation. Government should therefore design unique action plans for all potential communities to be affected.
iv. Mining companies should not just pay compensation to residents whose land has been acquired for mining. Paying compensation and resettling residents is inadequate in solving the socio-economic problem that can be created by mechanisation. Government and mining companies should collaborate to design and implement alternative livelihood strategies for communities whose farms and source of livelihood will be destroyed by mechanisation.
v. As part of employee welfare policy of the mine, workers should be counselled and supported prior to retrenchment by way of identifying what skill they have acquired that will be useful in securing them a new source of income. This will reduce the number of retrenched workers who join the "galamsey" team as uncertified "galamsey" engineers.

References

Bilim, N., & Kekeç, B. (2016). *Fully mechanized excavation system in underground coal mining*. Paper presented at the 2nd International Conference on Science, Ecology and Technology.

Boulter, A., & Hall, R. (2015). Wireless network requirements for the successful implementation of automation and other innovative technologies in open-pit mining. *International Journal of Mining, Reclamation and Environment, 29*(5), 368-379. Available at: 10.1080/17480930.2015.1086549.

Castro, R., Riquelme, J., Widzyk-Capehart, E., Hekmat, A., & Baraqui, J. (2015). Automation fundamentals of continuous mining system. *International Journal of Mining, Reclamation and Environment, 29*(5), 419-432. Available at: 10.1080/17480930.2015.1092664.

Ghodrati, B., Hadi Hoseinie, S., & Garmabaki, A. (2015). Reliability considerations in automated mining systems. *International Journal of Mining, Reclamation and Environment, 29*(5), 404-418.

Laflamme, M. (2002). Mine mechanization and automation at CANMET, Natural Resources Canada. *Journal of the Southern African Institute of Mining and Metallurgy, 102*(3), 131-138.

Miller, C. (2009). *Process optimization in mining: The next paradigm shift in productivity gain after mechanization and automation.* Paper presented at the Proceedings of the 34th International Symposium on the Application of Computers and Operations Research in the Minerals Industries, Vancouver. CIM, Montreal.

Mundry, S., Gajetzki, M., & Hoseinie, S. (2015). Longwall automation—productivity and coal quality enhancement. *International Journal of Mining, Reclamation and Environment, 29*(5), 357-367. Available at: 10.1080/17480930.2015.1086552.

Nong, S. (2010). *Review of successes and failures of mechanisation trials on platinum mines of the Bushveld Complex*. Johannesburg: Masters Research Report, University of the Witwatersrand.

Nong, S., & Musingwini, C. (2011). *Successes and failures of mine mechanisation trials on platinum mines of the Bushveld Complex in South Africa.* Paper presented at the Proceedings of the 20th International Symposium on Mine Planning and Equipment Selection, Kazakhstan.

Paraszczak, J., Gustafson, A., & Schunnesson, H. (2015). Technical and operational aspects of autonomous LHD application in metal mines. *International Journal of Mining, Reclamation and Environment, 29*(5), 391-403. Available at: 10.1080/17480930.2015.1086553.

Vogt, D., & Hattingh, T. (2016). The importance of people in the process of converting a narrow tabular hard-rock mine to mechanization. *Journal of the Southern African Institute of Mining and Metallurgy, 116*(3), 265-274. Available at: http://dx.doi.org/10.17159/2411-9717/2016/v116n3a8.

Willis, R. P. H., Dixon, J. R., Cox, J. A., & Pooley, A. D. (2004). *A framework for the introduction of mechanized mining.* Paper presented at the International Platinum Conference - Platinum Adding Value, The South African Institute of Mining and Metallurgy, 2004.