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Analysis of factors and suggestions for improving labour productivity in underground metal mines

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ABSTRACT

Despite the new age of industrial mechanization, the mining industry across the globe has been using a large number of labourers to achieve organizational objectives. Improvement of productivity becomes an important goal of any mining industry to achieve price competitiveness. The challenges for the industry are to identify areas of waste, meet the market demand and improve the net revenue. The most effective way of increasing productivity in the mine is the effective utilisation of mineworkers. In this paper, the effective working hours of workers in the underground mine were determined and the causes of delay in completing the single cycle of operation starting from face marking for blasting to rock bolting for support were analysed. It was found that the effective utilization of manpower is 70.8% in a single shift. Hence, one of the important factors affecting the mine's productivity is the effective management of manpower. As a result, various suggestions were provided for improving the productivity in the mine.

HIGHLIGHTS

- The effective utilization of labor in underground metal mining was examined.
- Mining enterprises were found to be at fault for the inefficient use of workers.
- The causes of the deviation and delay in the mining operations were found.
- This study suggested ideas for improving workers utilization.

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1. Introduction

In the age of digitalization of the economy with appropriate economic development drivers such as neurotechnology, artificial intelligence and big data, augmented with virtual reality, and communication through wireless technologies, it is almost impractical to develop models of effective management for increasing the productivity of labour (Kudryashova et al., 2019). Manpower utilization analysis typically includes qualitative, quantitative and empirical relations, technologies like the implementation of tracking systems which are completely online for indoor positioning using wireless radio communication systems, called construction labour tracking system (CLTS) and integrating it with GIS will help in improving manpower productivity and identifying the reasons for delay and deviation in mining operations (Shirowzhan et al., 2019). The shift to conventional energy sources has increased the pressure on mining enterprises in their ecological and economical sector (Helman, 2012; Brodny and Tutak, 2018; Tutak and Brodny, 2017). It has motivated the mining sector companies to take a series of effective measures. The measures should include activities that focus on reducing production costs and improving labour efficiency. This process has led to the identification of areas that can possibly reduce the cost of mining operations without incurring any investment costs.

Another important factor responsible for increasing the productivity of mines is the effective utilisation of labour resources. It is in direct relationship with the production efficiency of the mine and proper operations of the mining industry. This factor helps in increasing the net revenue generated by the company. It focuses on improving staff and talent utilisation by concentrating on both work activities and the employees who perform these activities. In a mine, manpower plays an important role in determining the productivity or output per man shift (OMS) and, therefore, it should be optimized. Hence, for a particular production, if the manpower is reduced, OMS will increase. One of the important factors responsible for optimising the cost of the mining industry which was investigated in an underground gold mine in Saudi Arabia was labour utilization and labour productivity (Aljuhani, 2002). In that mine, it was found that utilization of manpower in productive work was only 65% of the total shift time and the rest 35% of the total shift time was spent in non-productive activities. Thus, lower utilization of manpower will result in higher labour costs. Therefore, ineffective or underutilization of manpower will adversely affect labour costs as well as the productivity of the company.

There are many other factors also responsible for the improper functioning of an underground mine, such as delays in the cycle of operation, machine efficiency and lack of manpower management (Mishra et al. 2013). One such area of concern for reducing the company investment cost is the maintenance of the machinery. Machines which are well-conditioned are effectively utilised by the operator and increase the productivity of the mine. A problem arises in analysing the utility of machines employed in mines. This problem arises due to unpredictable physical environmental conditions in which the exploitation of the machines is carried out. Effective use of resources is a major factor which impacts the productivity of the mines. The mining industry plays an important role in every developing country's economy. A few parameters that have already been identified earlier for reduced productivity in the mine and utilisation of manpower are late reporting of the mine workers to the work site from the scheduled

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time, an unauthorized and unsanctioned break of workers, absence from the work site without intimating the person in charge, unavailability of tools on the work site, worker leaving early from the work site (Tomlingson, 1998).

Operations in mining are performed in sequential order, which means any operation cannot surpass its preceding operation. The main objective of effective manpower utilisation is to ensure employees possessing the right skills are in the right place at the right time. Thus, there cannot be any delay or postponement, as in preceding activity will affect the other operations that are needed to perform afterwards. Hence, it will eventually result in a dip in production. The parameters defining the level of productivity of labour is their share of the economy in the extractive industries (Bufetova, 2017; Mikheyeva, 2015). The costliest and most crucial resource of the company is human resources since it is one of the major inputs for any company to survive (Jonek-Kowalska and Turek, 2016). The per unit cost of mine production depends upon utilising the manpower and the level of production of the mine. The unit cost incurred by the mining organization is inversely related to the mine production. The best combination is when the level of production equals production capacity (Khasheva and Golik., 2015).

Previous studies only show the effective utilisation of manpower. In this paper, “the mineworkers” actual working hours per shift were compared to expected working hours to spot reasons for irregular shift time operations along with an estimation of delay for one cycle of operation of an underground metal mine located in Bhilwara district, Rajasthan, India. Data were statistically treated to deduce the causes of delay in operational time and suggestions were provided for improvement.

2.0 Materials and Method

Bhilwara deposit forms a part of the pre-Aravalli Banded Gneissic Complex consisting of gneisses, schist and intrusive of acidic and basic igneous rocks that occupy, predominantly, the southeastern plains of Ajmer and Bhilwara. The state of Rajasthan is enriched with the largest lead-zinc ore deposit in the country. Important lead-zinc deposit in the state is located in Udaipur, Rajsamand, Bhilwara and Ajmer (Department of Mines & Geology). The mine studied in this paper is located in the Bhilwara district of Rajasthan.

The effective working hour of a single shift is analysed. It is done by noting down the timing of personnel carriers (PCs) i.e. the time at which they leave the surface for the underground mine (In-time) & the time about which they return to the surface from the underground mine (out-time). In an ideal situation, the effective working hours in an underground mine should be around 8 hours including the time of allocation. The methodology included the study of the delay in the mine working to complete the single cycle of operation. The parameters considered to study the delay in the operation cycle of the mine include face marking, face drilling, charging, site clearance and blasting, fume clearance/re-entry, mucking, loose scaling, bottom mucking, rock bolt drilling, capsule loading, rock bolt grouting. The ideal time and actual time to complete one cycle of operation were recorded for interpretation of the delay. A workflow of the methodology adopted in this study is presented in Figure 1.

The transit time of mine workers from entering the mine by PC (personnel carrier) to exiting the mine by the same PC during their respective shift hours was recorded to estimate the efficiency of labourers in completing different operations of the mine. After analysing the average and ideal time needed for the completion of a cycle of operations in the mine, the delay factors in the working of the mine operational cycle were also investigated. Based on the identification of factors responsible for delaying the regular mine working cycle, certain suggestions were also provided to increase the productivity and efficiency of the labourers.

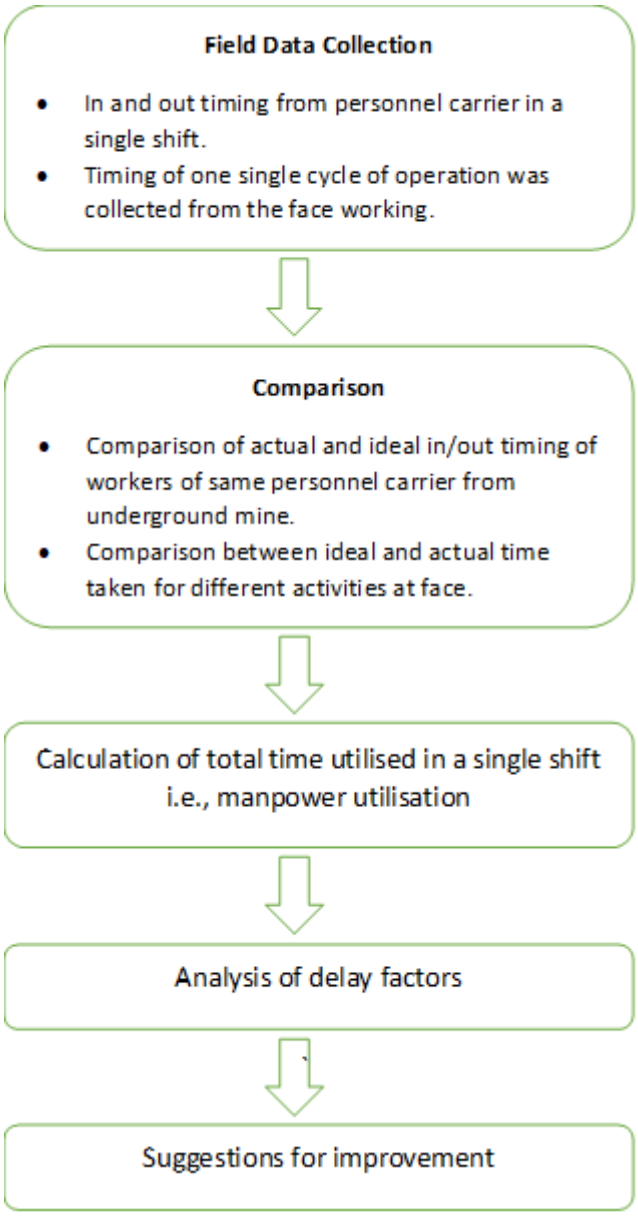

Figure 1. Methodology adopted for analysis of delay in a single cycle of operations

3.0 Results and Discussion

The comparative study of the ideal time (time of maximum output reported by the mine) and actual time taken by the worker to complete the operation and the difference in timing are compared which is represented in Figure 2. A time gap of 2 hours is observed between the ideal time to be spent and the average time that has been taken to complete one single cycle of operation.

The delay in a cycle of operation observed is due to the unavailability of PCs, either due to breakdown and maintenance work of the equipment or late arrival of the next shift workers to the surface. The roadways in an incline underground metal mine get stuck several times due to heavy traffic and blockage of levels.

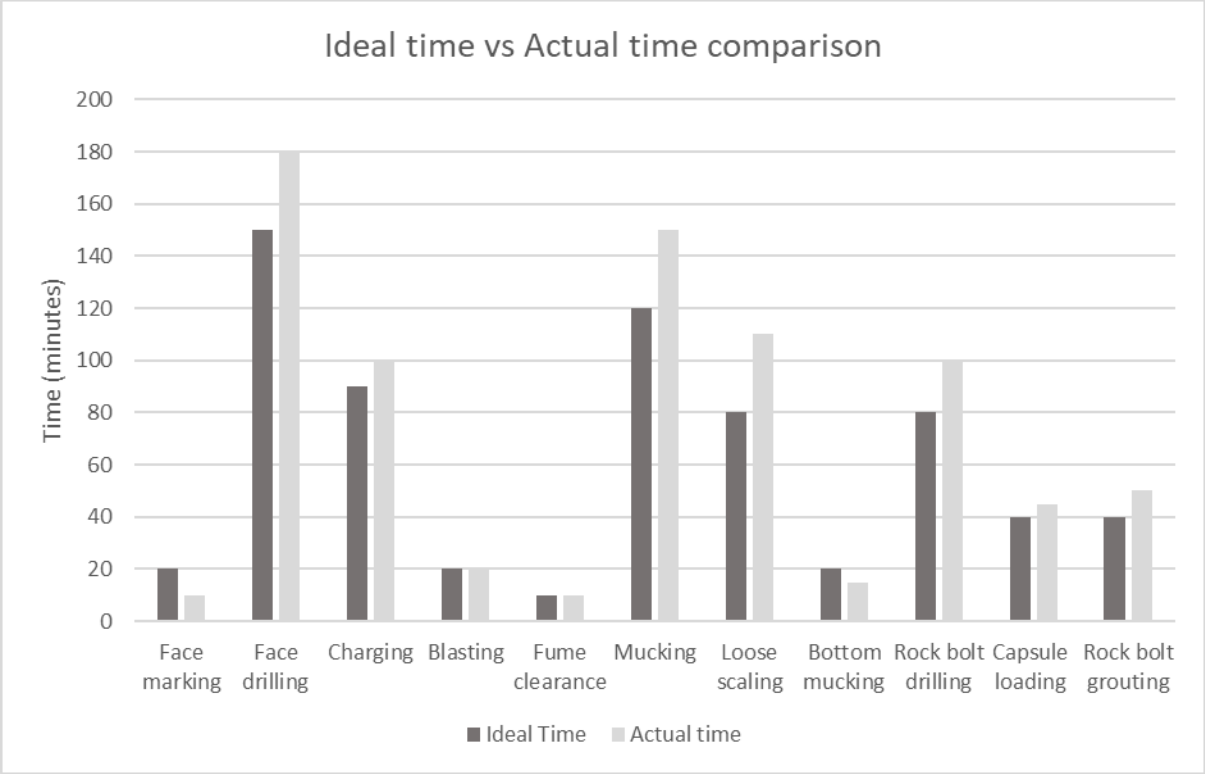

Figure 2. Comparative study of ideal time and the average time for completing a cycle of operations

Another factor identified for the delay in operations is shortage of cap lamps for the mine workers and they wait for the previous shift workers to return the cap lamp. Maximum delay can be seen in the drilling of a face which is rarely completed before the allotted time by the mine management. This delay is generally due to the unavailability and breakdown of machines. Improper ventilation in underground mines makes it tough for the mine workers to work in the crosscuts. Another factor that causes delays in the mining operation is power cut-off or the absence of pressurized air while using any pneumatic machines in an underground mine.

The in and out timing of mine labourers from the same PC in an underground mine was recorded in a single shift of the mine for one complete month and was also assessed to know the effective working hours of the labourers in the mine. The maximum time after which the labour came out of the mine was 6 hours and 10 minutes in an 8-hour shift. The minimum time of labour spent at the face of the mine was 5 hours and 20 minutes in an 8-hour shift. The time recorded for each day of a month for in and out of mine labourers from the underground mine through PC has been shown in Table 1. The effective working hours of

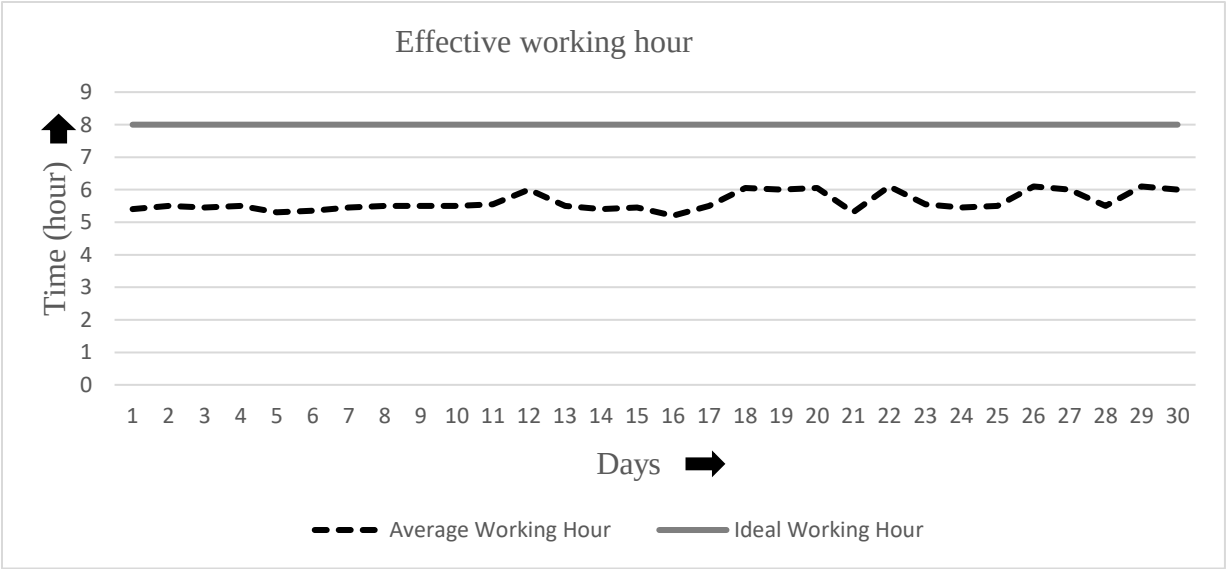

Figure 3. Effective working hours of mine labourers in 8-hour shift

Table 1. Total time mine workers spent at the face of an underground mine

Day	Time In and Out of PC		Transit Time (hours)
	In	Out	
Day 1	7: 00 a.m.	12: 40p.m.	5.40
Day 2	7: 30 a.m.	1: 20p.m.	5.5
Day 3	7: 15 a.m.	1: 00p.m.	5.45
Day 4	7: 15 a.m.	1: 05p.m	5.5
Day 5	7: 30 a.m.	1: 00p.m	5.3
Day 6	7: 45 a.m.	1: 20p.m	5.35
Day 7	7: 15 a.m.	1: 00p.m	5.45
Day 8	7: 10 a.m.	1: 00p.m	5.50
Day 9	6: 50 a.m.	12: 40p.m	5.5
Day 10	7: 15 a.m.	1: 05p.m	5.5
Day 11	7: 15 a.m.	1: 10p.m	5.55
Day 12	7: 00 a.m.	1: 00p.m	6
Day 13	6: 55 a.m.	12: 45p.m	5.5
Day 14	7: 50 a.m.	1: 30p.m	5.4
Day 15	7: 15 a.m.	1: 00p.m	5.45
Day 16	7: 10 a.m.	12: 30p.m	5.2
Day 17	7: 10 a.m.	1: 00p.m	5.5
Day 18	7: 00 a.m.	1: 05p.m	6.05
Day 19	7: 00 a.m.	1: 00p.m	6
Day 20	6: 50 a.m.	12: 55p.m	6.05
Day 21	7: 10 a.m.	12: 50p.m	5.30
Day 22	6: 50 a.m.	1: 00p.m	6.10
Day 23	7: 10 a.m.	1: 05p.m	5.55
Day 24	7: 15 a.m.	1: 00p.m	5.45
Day 25	7: 30 a.m.	1: 20p.m	5.50
Day 26	6: 50 a.m.	1: 00p.m	6.1
Day 27	7: 00 a.m.	1: 00p.m	6.0
Day 28	7: 10 a.m.	1: 00p.m	5.50
Day 29	7: 00 a.m.	1: 10p.m	6.1
Day 30	7: 00 a.m.	1: 00p.m	6

mine workers for a period of one month have been represented graphically in Figure 3. These data were analysed and it was found that the average effective working hour of mine labour in an 8-hour shift is 5 hours 40 minutes which is 70.8%.

3.1 Suggestions for improving manpower utilization

An attempt has been made to suggest the improvement of manpower utilization in a metal mine after visiting the mine continuously for a month. The mine management should keep some extra personnel carrier (PC) in reserve so that the operations of mining are not hampered if any breakdown of PCs occurs. Proper communication should be made between the machine operators to enhance the speed of movement between different levels. Preventive or periodic maintenance of the equipment should be done on a regular scheduled basis to avoid any breakdown of machines. Parts of the equipment that need regular maintenance should be checked daily or weekly, depending upon the need for maintenance. Training classes for the usage of different equipment should be organised to make workers more efficient. A proper ventilation plan should be implemented in an underground mine for mine workers to work efficiently. A plan of providing incentives should also be considered for motivating the mine workers to work more efficiently. The supply of power to the equipment should be regularly checked to avoid any chances of a power cut and halting the production of the mine.

4.0 Conclusions

There are several factors affecting the productivity of a mine; operation cycle, efficiency of the machine and managing manpower efficiently. Among them, one of the major factors

affecting the production of the mine is the effective management of manpower. Productivity in an underground mine is highly influenced by the utilization of manpower employed. This study found the effective timing of utilization of manpower which came to be 70.8% of a single shift. Factors which cause delays are identified in the operation of the mine and deviate from the whole mining operation. Many of the recommendations in this study, such as regular preventive or periodic maintenance of the equipment to avoid machine malfunctions and regular power supply to the equipment to eliminate any dangers of a power outage and disrupting mine output, are simple to implement and will improve mine productivity.

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