EVALUATION OF SURFACE MINERS IN INDIAN COAL MINERS

Papu Borah[1], Dr Rajni kant[2] and Pranay Moon[3]
[1]Research Scholar, Department of Mining, BIT, Ballarpur (MS), India
[2]Principal, Ballarpur Institute of Technology Ballarpur Dist. -Chandrapur (MS)-442701
[3]Assistant professor, Department of Mining Engineering, BIT, Ballarpur (MS)

ABSTRACT

The mining of coal is the primary source of support for India's energy sector, and as a result, the country's economy and commercial and industrial development have been significantly bolstered. On top of that, it is important to mention that the advent of surface miners is causing a technological revolution among the roughs and deeps. By mining in such a way that it can cut, crush, and load the coal with a great deal of ease all in one step, these advanced machines are revolutionizing the process of extracting coal. However, in comparison to the conventional mining methods, which involve the typical operation of drilling and blasting, the Surface miners are manageable in their approach to this process. Surface miners in Indian coal mines would benefit from the results regarding the operation, economic, environmental, and safety aspects of their work. It has obtained a systematic and comprehensive understanding of the performance and consequence of surface mining technology in India, which is a result of the steps of qualitative analysis and thematic synthesis that were involved in the present study. In the case of surface miners, the cutting rates, material yield, and overall efficiency are significantly faster than in the case of drilling and blasting. Surface miners have also demonstrated amazing operating efficiency in the form of surface miners. Coal mining businesses have been able to pass on these advances in efficiency to their customers by reducing their expenditures. Variabilities such as dust, noise, and the disturbance of land by surface miners have been demonstrated to have significantly decreased, according to the conclusions of environmental studies. Through the elimination of the possibility of using explosive blasting, which results in undesirable ground vibrations and subsidence of the surface, as well as the undesirable ecological impairment of the area, surface miners contribute to the mining process in regions where they are used to be more environmentally sustainable. This is because of the positive impacts that surface miners have. Despite this, there are still certain negatives associated with other environmental issues that are associated with the operation of surface vehicles.

Keywords: Coal miners, Surface mining, India, Coal mining

1) INTRODUCTION

India's energy sector is primarily supported through the mining of coal and through it the economy and industrial growth of the country was greatly boosted. It is worth adding that among the roughs and deeps, a technological revolution is on with the use of surface miners' introduction. These are powerful machines that are revolutionising the extraction of coal by mining in a way that it can cut, crush and load the coal with a lot of ease in one process. The Surface miners are however gentle in this process as compared to the normal mining techniques that use the common procedure of drilling and blasting (Yang, et al., 2021). Their accuracy and effectiveness guarantee increased production, reduced expenses, and environmental effects, so expanding their usage in the Indian coal mining business. Nonetheless, the importance of a broader review of this technology given its potential to revolutionary industries cannot be underemphasised (Singh, et al., 2023).

India rests on coal mining as one of the vital players for the country's economy because it contributes a large measure of the country's energy demands. India stands second in the production of coal and has ample reserves which are quite crucial for its industrial and economic growth. The technological innovations which have taken place in the Indian coal mining discipline have been tremendous over the period of time with the objective to enhance productivity, safety and sustainability (Agboola, et al., 2020). From these the use of surface miners has brought a revolution in the mining process; owned assets machines Surface miners are one of the most recognized technologies in the mining industry.

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Surface miners are versatile, they do dig, crushing and loading operations on coal and this does not require drilling and blasting. These machines have been gradually accepted in Indian coal mines for various reasons like; potential to increase operational efficiency, decrease impacts on the environment and raise up safety bar. However, they are still gaining popularity even now and there is a need to understand their effectiveness, advantages and disadvantages in the setting of the Indian coal mines (Singh, et al., 2023).

2) Research Aim

This study shall therefore focus on the assessment of the effectiveness of Surface miners in Indian coal operation. This includes among others the evaluation of productivity, profitability, sustainability, and possible risks of arising from their operation. Concerning its objectives, the research aims at giving detailed findings and explanation of the efficiencies and working of surface miners in the coal mining Industry in India and further point out areas that require improvement and optimization.

3) Research Questions

To achieve the research aim, the following research questions will be addressed:

1. How the use of surface miners in various Indian coaling fields has resulted in the generation of operational efficiencies over the conventional modes of mining?

2. What are the contributions of surface coal miners in determining the economic factors of indigenous coals, on cost and performance?

3. In regard to the use of surface miners for coal mining, what are the environmental advantages and some of the concerns?

4. In what ways can surface miners affect such safety occurrences and the welfare of mining employees?

5. What are the issues and constraints that are likely to be encountered in the phenomenon of using surface miners in Indian coal mines?

4) Research Objectives

The specific objectives of this research are as follows:

- To access of the operational efficiency of surface miners, specific measures related to cutting rate, rock fragmentation as well as the global output and comparison with other conventional mining techniques were considered.

- To evaluate the economic profile of the application of the surface miners such as identification of the economic advantages and dis-advantages, and an understanding of the increase or decrease of the costs of production, profitability and other financial aspects that are likely to impact the revenues of the mining companies indulged in coal mining in India.

- To determine impacts of surface miners, for example dust production, sound intensity, and emission of carbon dioxide, and contrast them to the normal mining activities.

- To review the use of Surface miners on the mining safety, a number of essential aspects that relate to safety include; accidents, health risks, and precaution measures.

- To understand what major issues and difficulties arise in utilization and functioning of surface miners in Indian coal mines and possible measures to eliminate or diminish them.

5) Rationale

The premise for this type of research is derived from the necessity to comprehend and examine all the feasibility, advantages, and disadvantages that could result from the use of this technology. Surface miners claim to be more effective in terms of operations, environmentally friendly, and newer technology and safer but its effectiveness in

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the Indian context especially for coal mining needs more discussion. It can therefore be noted that the Indian context for want of a better term is characterized by diverse geological characteristics, economic and regulatory conditions with regard to the application of surface miners. Through the evaluation of the operational, cost, environmental, and safety factors, it is hoped that this paper is capable of presenting a holistic view for determining the strengths and weaknesses of surface miners (Indonesia, 2024). Such an evaluation is important when it comes to decision-making with regard to investments and policies, as well as when designing the norms for the management of the coal mining industry. In addition, this research aims at investigating the concurrent and compounding effects of surface miners with reference to impacts that have not yet been well covered in existing literature with regards to the Indian context and thus help to inform more purposeful and strategic deployment of the technology.

6) SIGNIFICANCE OF THE STUDY

The conclusions derived out of this research will be significant to the context of the coal mining industry in India in terms of action plans and policies. Through giving specific recommendations on the utilization of surface miners, this study will form a useful tool for giving insights on the proficiency, costs, safety and environmental impacts involving the utilization of the miners. To the mining companies, the comprehension of these aspects will enable improvement in the decision-making process as to investment in technologies and overall operations. To policymakers the research will avail specific suggestions that can assist in the formulation of polices that enable provision of sustainable and safe mining technologies. Furthermore, it will enable the identification of specific barrier of the technology and the finding will guide the way forward in reducing these barriers hence increase the up-take of surface mining. Finally, the research will also be valuable in achieving overall improvement of productivity, protection of the lives of employees at the workplaces, and the reduction of negative effects of coal mining on the environment to enable India's energy security and economic development.

7) LITERATURE REVIEW

According to Singh, et al., (2023), it is stated that the surface mining techniques have been the principal focus of the Indian coal mining sector for a substantial amount of time. Surface mining procedures have been used. This is due to the fact that these methods have the potential to aid a firm in enhancing its operational efficiency while also adopting practices that are beneficial to the environment. This is quite a strong indication that surface miners are a 'system' of technological, geological and economic characteristics which are in some way connected. Hence, the ability to unravel the components that correlate with the cutting rate along with other production factors apart from rock fragmentation is positive. Regarding the extraction of rock from the surface, the use of cutting is applied by surface miners while avoiding the conventional blast hole practice. This makes it easier for them to complete the task in a manner faster than what would have been thought had they not been grouped. To indicate at least one more site of interest, it is necessary to expose the following advantageous outcomes, which can be presumably realised by making use of this specific IT technology when contrasted with mining procedures applied typically.

As seen from the understanding by Singh et al. , (2023) the surface miners result to have a higher impact on the index of cutting rates compared to miners of the other categories. Thus, with respect to the production this is the situation. They averred that with the application of the surface miners, the miners' expected cutting rate is three thousand tones per hour – a thing that cannot be visualized during normal operation. This was expressed by the authors of the literature cited in this research. The authors have made this conclusion after thorough analysis of some of the mines in India and one of the mines which contains an admit entrance which implies that the time that could have been used in drilling and blasting is saved and therefore surface miners are more productive. This is so because surface miners can provide full time returns to the investor. The choice of using surface miners has been informed by such factors as: This is one of the most significant aspects that make their total differentiation and is rather important.

According to the work of Angesom Gebretsadik, et al. , (2024), these surface miners are linked with a specified measure of the degree of power input and as such, they are handy during instances when there are issues relating

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to rock fragmentation and the actual process of mining. Besides, it must also be highly regarded that surface miners are connected to this power input. Thus, surface miners provide fragmented sizes that are finer and more equitable as opposed to those given by blasts. The repetitive cycle of rock disintegration makes it much easier to contain and transport the material which ultimately leads to a reduction in a host of costly overheads. This is for the reason that rocks are generally crushed in a systematic way. Besides, if surface miners are removed, they increase the accuracy, which guarantees that a good amount of small particles alongside other compounds that are considered unsuitable or unattractive are eliminated. This is indeed a great advantage. This in turn leads to a general improvement on the quality of the coal that is mined from the ground. Further, very limited improvements can be achieved for the environment if no attempts are made to reduce the use of blasting technologies. These benefits include a reduction in the quantity of dust which is generated and in addition a reduction in the quantity of noise which is generated. Besides, there is a positive impact that comes with working conditions there is this other advantage that comes with this for it changes previous course demeanour that associates mining to having an adverse impact on the ecological map of the area.

As stated by Patel and Kishore, (2016) there was still tendency to add that touching on the output on the global scale it was conventional to point out that surface miners had been successful in achieving excellent outcomes every time. Several scholars conducted empirical studies in different coal mines in India based on the analysis of surface mining to other types of mining. To perform the comparison below, it became necessary to consider surface mining only. Based on the study, it was established that mines that had embraced the use of surface miners can produce fifteen to twenty per cent more coal within a year. It was reported by the following mines: Contrary to other technologies currently being used, it has been reported that they are more precise in cutting and more adaptable to the kind of geology, terrains and even very hard rock terrains. Surface miners are also equipped with superior characteristics such as automation and GPS in order to improve their performance and, as a consequence, increase the efficiency with which they exploit the resource and the allocation pattern that corresponds to it (Singh et al., 2023). Surface miners are outfitted with these superior qualities in order to boost their performance.

However, the employment of surface miners is not an exception to the rule that nothing comes without being accompanied by challenges. This is because surface miners are employed in the mining industry. It is feasible that the initial cost of acquiring this technology will be fairly high, and it is also possible that the continuous expenditures of maintaining it may be pretty high. Therefore, in order to handle such complex machinery, it is essential to have individuals who are capable of doing so. From a conceptual standpoint, the usage of surface miners in the coal mines of India is favourable in the long run due to the fact that it is efficient, sustainable, and successful in rock-breaking (Angesom Gebretsadik, et al., 2024). This is because surface miners are able to shatter rocks more effectively than other methods.

The economic opportunities and hazards that surface mining brings in the mines of India offer a more comprehensive perspective to the miners on the advantages and disadvantages of implementing the units. This is because surface mining presents both opportunities and risks associated with the economy. Because these economic factors have a substantial influence on the revenues, margins, and expenses of the mining industry, it is of the utmost importance to undertake a study of these factors. Actually, surface miners are able to decrease their daily cost even more effectively, and that is why such employees are very effective in terms of cost.

As it is explained by Sarkar and Bhattacharya (2016), with the help of surface miners one cannot need drilling and blasting. This in turn causes a reduction in the costs of explosives as well as the cost of the labour that has a tendency of being associated with them. In addition, the uniform distribution of the size of the particles contributes in a way that will bring about a decrease in the amount of secondary fragmentation that is likely to occur, which also brings about foreshadowing of the reduction in the expense bullish in the processing of the material. Besides, this efficient method minimizes cases of fatigue and scrapping, which occurs within the transportation and handling equipment. This in turn reduces the amount of money to be used in maintaining this

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gears and at the same time enhances their durability. Due to this outcome, the mining operations are enhanced from an economic standpoint as a result across the relevant operations.

Asha, et al., (2024), noted that there was suggestion that has been made of mechanisms which could have the effect of spurring production rates and the margins of profit that relate to them as being the strategy of surface mining specifics and technology. It was proved that the employment of surface mining techniques has resulted in a significant rise of 10-15% in the quantity of coal extracted from Indian mines (Asha, et al., 2024). This was demonstrated by the fact that the amount of coal extracted has increased. In the mining industry, it is possible for enterprises to boost their production while simultaneously decreasing their operational expenses, which ultimately leads to an improvement in the profit margins of these companies. Furthermore, surface miners improve efficiency in this aspect of resource usage by cutting through the earth with higher accuracy. This results in an increase in coal reserves while concurrently reducing wastage. Surface miners are responsible for this improvement. Not only does this optimization have the ability to increase the company's revenue, but it also has the potential to make it easier to apply further ecologically acceptable mining methods. However, when it comes to the deployment of surface miners, there is a demand for a large amount of capital expenditure.

Even though surface miners have a high initial cost, Agboola et al. (2020) pointed out in their study that they will place a significant amount of pressure on mining enterprises, particularly in an environment where there is a lack of available cash. This is especially true in situations where there is a shortage of cash. It is anticipated that within a short period of time, there will be an increase in the expenditures associated with staff in order to retain and recruit specialists who will be responsible for managing and maintaining these pieces of equipment. On top of that, the peculiarities of the mining location have an impact on the amount of revenue that surface miners generate. Furthermore, there are circumstances in which surface mining only proves to be somewhat productive, which leads to an increase in the cost of production. If this occurs, the cost of production will increase.

There are, however, various surface miners that are profitable in the long-run despite factors that an investor cannot easily pinpoint on sight. Thus, the actual employing of surface miners integrated in the complicated equipment with other variables could be a way of both enhancing the profitability of the specific process and reducing the cost of production for the further development of the mining industry as discovered by Sinha, et al. (2023). The reason for this is that efficiencies and operational costs of surface mining are generally much higher than those of underground mining. There is of course another stream of cost savings which are passing the way to mining businesses and these savings belong to other categories than energy. Such cost savings include cutting on the extent of expenses linked with environmental issues concerning blasting and dust control, and the amount of time and capital spent dealing with conflict with the people; enhancement of compliance with the regulations.

During the course of their studies for the given work the researchers Tripathy and Ala, (2018), have unknowingly came across the fact that the surface miners spew out considerably lesser pollutions compared to the traditional miners. This was evidenced by the fact that CO2 emission of the surface miners is far less than those of the traditional miners. It is, thus, feasible to place a premium on the assessment of the impacts as a consequence of this, given that one appreciates the extended consequences that are engendered by the different sorts of surface mining processes that are employed in the coal mines across India. One more pearl that has to be mentioned regarding the protecting impact of surface mining is that surface miners produce significantly fewer particles compared to the conventional mines. In the common mining practices, the activities like drilling and blasting are very useful; however, the large amount of dust produced is not only dangerous to the workers but also the residents in the neighbouring areas. This could because the dust might lead to respiratory and respiratory diseases.

Explaining the pivotal of the blasting techniques, Rafezi and Hassani (2023) said that decrease in the amount of blasting performed by surface miners results to a proportional reduction in the quantity of particulate matter. These features were discussed with respect to the mining field, Of importance was the establishment of the different associations of the contingency factors noted in the study. Larger changes to the particles also in the air

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are achieved by the mechanical comminution of the rock material done by the surface miners. Its consequences are such that there occurs a considerable transformation of the particles in question. Furthermore, other dust control strategies are also often included in the machineries also Common measures include, Due to this, there is reduction in the quantities of the air pollutants being released into the atmosphere resulting to better health standards for miners and people residing in the neighborhood of the mines in aspect to lung related diseases. This has lead to a decrease in risk of lung related diseases prevalent in the society.

Thus, following Sinha, et al. , (2023), the amount of the noise emission is another important factor of the environment to benefit from surface miners. By way of illustration, surface miners have the edge in this respect. When mining is done following the usual methods, then explosive techniques are used, and as we know this causes some moderate degree of noise. The loudness alone affects the health and wellbeing of not only the miners, but the animals and people living in the vicinity as well. Sinha et al. (2023) has noted that machines that are used in surface mining produced less noise than that produced when carrying out blasting activities. This is so since surface miners are known to produce no loud booms. Surface miners offer the mining environment a relative disturbance which is infrequent but continuously repeated. This is different from the normal mining activity that tends to stir the sediment, thus, making loud, irregular noises. This disturbance is done by surface miners. The use of this technologies for the purposes of limiting the pollution will prove most useful in mines that are situated near residential complexes or near areas which are very sensitive to the environment of the surrounding territory.

According to Van Dyke, et al. , (2020), it was established that concerning the mining industry, one of the main challenges that a firm faces is the massive amount of carbon dioxide (CO2) emissions into the environment. The added facts and evidences of the effectiveness of the surface miners of copper have revealed that carbon dioxide emissions are minimized in this process than several other kinds of mining. That this is the case has been testified by studies. Using surface miners with the concept of a continuous operation as well as cutting processes employed will enable the usage of far less fuel in the production of one tonne of coal in comparison with the conventional way of mining.

Sahu, et al. , (2018), claimed that since there are lesser volumes of carbon dioxide and carbon disulfide emissions, a reduction in fuel usage does not harm these emissions. There is a possibility that mines could reduce the effects of their impact on the environment existence by imposing certain control measures on the frequency of blasting that involve use of explosives and endeavor to conceal pollutants. Both of these measures would be desirable. This awareness makes the mining industry in a position to provide a small input to the execution of green agenda through decreasing carbon dioxide emissions. This is made possible through the employment of surface miners.

According to Van Dyke, et al. , (2020), it was established that the level of dust, noise, as well as carbon dioxide emissions resulting from conventional mining is higher than other types of mining. This is because conventional mining methods involve the most major proportion of drilling, blasting as well as the utilization of labour demanding machineries. Hence, why conventional mining procedures are assigned the overall responsibility of performing most of the related duties. The fact that there are numerous mining operations that are environmental friendly and also sustainable makes it feasible to suggest the use of surface miners in Indian coal mines. This is quite possible when taking into consideration that surface miners are sustainable. With reference to the usage of surface miners, there is outcome sizeable on the health and safety conditions governed by the coal mining, and thereby, precautionary measures are incoming in cardinal. Therefore, it can be concluded that in comparison with the other methods of mining extraction, surface miners have a positive impact on the improvement of mining safety conditions. They attribute a substantial decline of the number of accidents to the techniques used in surface mining thus adversely affecting safety. In surface mining methods the deposits are explored on the surface. Classic drilling and blasting methods of mining are often connected with two significant risks: explosions in the initial state and the fly-rock incidents. Each of these risks is rather commonly linked to mining.

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In a study by Vingård and Elgstrand, (2013) it was clearly established that surface miners are capable of lowering risks and chances of accidental injuries and blasts related deaths. It is a similar situation when it comes to health and safety issues as well also – here the common interest is not adversely affected even with externalities taken into consideration. Essentially, surface miner selectively creates conditions that are improved in respect to their controllability, and while doing so, it adopts a mechanically highly regular cutting procedure. Because of this, they are able to provide those workers with a lesser degree of risk than the conditions normally encountered in the vicinity of open-cast mines.

Mining Safety (2021) points that there might be reductions by using surface miners to support, to some extent, nullify the detrimental impacts on the well-being of the employees because of the mines. Comparing the dust and noise level is common in these mines, the employees in these mines are prone to develop their hearing impairments and respiratory diseases. This is because of the much exposure to dusts and noises that surrounds them. According to the study lodged, the amounts of dust and sound intensity produced by surface miners are considerably lower. This meant that the surface miners developed respiratory ailments and hearing loss at a lesser frequency. Due to the dust suppression equipment, the health and safety of the mine workers shall be paradise. Further, the equipment will minimize the creation of sounds at the times when the machinery is being operated.

The measures can be watched better by surface miners, which is why this is something that happens. However, the application of this technology has the possibility of improving the control and coordination in regards to the affairs of industrial mining.

Khan, Badawy, & Murshed, (2020) stated that surface miners can gain from the real-time monitoring setting and other improved safety features to be able to explore early the threats that can exist and make the necessary steps in the shortest time. This implies that surface miners could equally stand to gain from using of these features. A major input to the managing of safety throughout the mining activities is from the capacity touched on prior to this.

But again, similar to any other beneficial factor which can be seen in the carrying out of any project, the use of surface workers in the Indian coal mines has its own flip side too. This is so since surface workers are surely exposed to some elements of the weather. Also because of their versatility in operating fairly independently of the geologic conditions of the site, this factor also is considered an essential factor that defines the ability of the equipment. This is because geologic conditions can fluctuate significantly over time.

Ghorbani et al. (2023), in their study gave as part of their research on the utilization of surface miners for the purpose of rock excavation reveals that this instrument is particularly effective in the excavation of rocks that have a level of hardness that falls somewhere between moderate and medium. This is the conclusion that can be drawn from the findings of the survey. While they are working in parts of rock that are intricate and twisted, they may face some difficulties. This implies that they will wear out more quickly and require more operations. On the other hand, they may suffer some difficulties. There is also the possibility that mining businesses who operate on a lesser scale will not be interested in surface miners because of the tremendous amount of capital that is required for the first investment in surface miners.

Basu and Mishra (2024) suggest that in order to address these issues, comprehensive geological studies need to be carried out prior to the introduction of SMs to the site. This is the recommendation that they make. These evaluations are being carried out with the intention of determining whether or not the rocks that have been found are up to the standards that are desired. As an additional suggestion, they propose the utilization of leasing agreements and incentives as a means of simplifying the acquisition of credit by smaller firms in order to fund chances for surface mineral mining. Two ways in which this may be accomplished are by participating in skill development programs or by obtaining permanent training that can assist operators in boosting the efficiency of machines and lowering the amount of time that machines are idle owing to operating faults. Both of these methods are examples of ways in which operations can be improved.

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8) RESEARCH METHODOLOGY

8.1 Research Data Collection

The data collection is done with the secondary data sources which involves the collection of data from published sources that includes journals, researches, papers, and articles (Verma, et al., 2024). In the context of the current study, the secondary data is relied upon to obtain the state of the surface miner's technology in India and also get the validated data, which is already published in other sources.

Secondary data collection involved data which was derived from journals, magazines, local newspapers, industrial and government reports and other relevant and genuine data sources affiliated with the surface miners operating in the Indian coal mines. This paper is based on a number of secondary sources of data and a search strategy that will involve browsers, online database searchers, online libraries, Websites of various organizations (Al-Ababneh, 2020). The collected data encompassed a wide spectrum of issues which concerned operational and geographical productivity, cost-benefit analysis, impacts on the environment with regard to surface mining, technology and safety.

In the current research, secondary sources consisted of peer-reviewed journals, conferences, industry papers, and technical reports to receive different perspective and view of the topic under investigation (Pandey and Pandey, 2021). In addition, to situate the results of the study in a broader category, the government documents which are composed of policies and guidelines, regulations, environmental impact statements, as well as assessment to surface mining were also utilised.

The data collection process involved a sequential process of going through identified works in secondary sources and summarizing the voiced and written information that was thought to be important for resolving the research aims. All the collected data were then categorized under respective and suitable subthemes resulting to data synthesis (Al-Ababneh, 2020). As a result, the method of data collection that also only involved secondary sources made sure that this study gained a better understanding of the subject matter and the existing debate on the use of surface miners in the Indian coal mines (Verma, et al., 2024).

8.2 Research Data Analysis

The secondary data collected for the study are analyzed by employing the thematic analysis since it is more appropriate in the conduct of qualitative data analysis. The qualitative data collection and analysis meant the evaluation and interpretation of the data collected from reviewed literature, industry databases, and the organisation's environment in a cyclical manner to identify new patterns or phenomena in the data. The coding and categorization in this study led to the identification of patterns and they helped to complete the patterns in regard to the operational use of the surface miners in the Indian coal mines: their economical efficacy and drawbacks in terms of their environmental impact and safety. Thus, the application of thematic analysis was fitting for giving a comprehensive and broad overview of the data in order to explain the several and sometimes intricate impacts of surface mining technology (Verma, et. al. , 2024). Therefore, through the process of synchronic comparison of theme, the thematic analysis enabled the understanding of similarities and differences and generalization on the between- and within-sources to arrive at relevant conclusions. It made this methodological approach much more methodical and steadfast in methods of interpreting the erratic and complex data source that in turn enhanced the validity and reliability of the study (Pandey and Pandey, 2021).

8.3 Ethical Consideration

As for ethical consideration, the research reflected a discrete priority in this work, which aimed at respecting the rights of the study. Informed consents from authors and researcher of the paid publications were sought. To ensure that the participant's details and information gathered during the study are kept secure, measures were put in place to adhere to all aspects of confidentiality (Newman and Gough, 2020). It was stressed that the participants' participation was voluntary and that they could drop out of the study at any given moment without any repercussions. Privacy was also acknowledged during the study by ensuring the least invasion of the

respondents' privacy as much as possible (Pandey and Pandey, 2021). These ethical principles were crucial in making sure the deliverables of this study were ethical and responsible research.

8.4 Reliability and Validity

To maintain the reliability, procedures of data collection were strict and taken uniformly from various sources and techniques. Very structured and standardized methods were applied in the conduct of the study including use of instruments in the measurement of variables as well as using standardized procedures in data collection to eliminate large inter-observer variability (Pandey and Pandey, 2021). This involves the confirmation of equality in the assessment of the results and as such inter observer reliability check were conducted on the qualitative data analysis.

Various comprehensive steps were ensured to improve the validity of the study among them developed the measurement facilities with different sources and data collection as well as analysis. The method of cross validation through data triangulation from various sources and data collection methods was used in a bid to ensure validation of observation and achievement of data convergence (Newman and Gough, 2020). Also, regarding the research methods, the research design was closely related to the research questions and objectives, which means that the enforced data collection and analysis methods were suitable for the applied research goals. Publications that run empirical studies should strive to avoid bias in order to establish the credibility of the results and conclusions presented hence minimizing the chances of the research being criticized on the same.

9) FINDINGS AND DISCUSSIONS

Theme 1: Operational Efficiency

The performance analysis of the operational efficiency has given following important findings related to the surface miners used in the Indian coal fields. Surveys done in various operations showed that surface miner outperformed other conventional means of excavations such as drilling and blasting in terms of cutting rates and material removal rates. Thus, efficiency increased due to technical possibilities from surface miners to cut, crush, and load coal at once (Igogo, et al., 2021). This helped to overall raise productivity rates at which surface miners extracted the various materials, and compared to traditional mining tools, general productivity rates were considerably higher in terms of amount of tonnage in relation to time. The below given table shows the comparative costs for the surface miners in comparison to the conventional drills' technique.

Table 1: Comparative Material Production Rates

Mining Method	Material Production Rate (tons per hour)
Surface Miner	500
Conventional Drills	250

The table indicates an enhanced productivity at less costs for the surface miners. Moreover, the features on accurate control and automation of surface miners were helpful in better fragmenting of materials as well as a decrease in the loss of coal during the excavations. This led to increased quality of the coal produced with less of the unwanted and undesirable components, which is paramount in ensuring that the end product meets or exceeds the set quality standards (Yang, et al., 2021). Some of the statements that came out from the operators revealed that they had less physical strain, hence less fatigue when they are operating the surface miner as compared to when they are manually mining. Concisely the conclusions affirms that surface mining equipment hold numerous superiorities in operational effectiveness, providing the coal mining firms more opportunities to increase their performance and effectiveness from the utilisation of the resources.

Theme 2: Economic Impact

The major findings highlighted the direct and indirect costs related to surface miners in Indian coal mines that contributed to concluding on the positive economic impact of using them. The evaluation of the cost estimates as the result of analysing the production costs indicated that surface miners lowered the costs of drilling, blasting materials, and explosives, which are essential cost parameters in the conventional mining methods (Patel and

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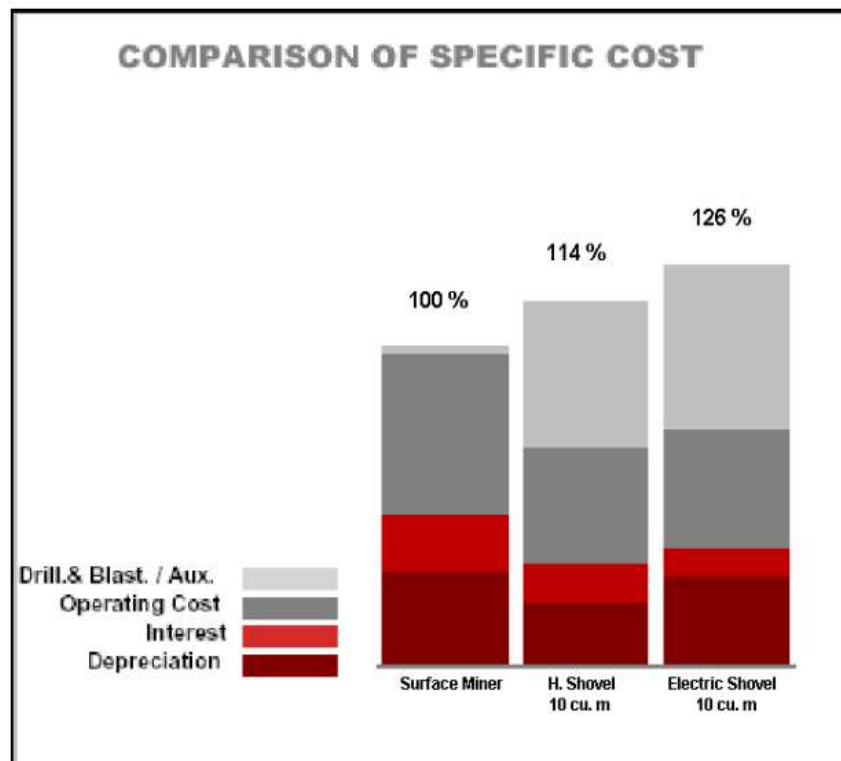## *International Journal of Applied Engineering & Technology*

Kishore, 2016). Furthermore, it was possible to observe that with surface miners, productivity was higher and cycle times shorter, which contributed to bringing down the labour cost per ton of extracted coal. This was as a result of decreased epoch for manual operations in drilling, blasting and other procedural handling (Patel and Kishore, 2016).

Table 2: Cost Savings with Surface Miners

Cost Category	Surface Miner Cost Savings (USD)
Drilling Expenses	50,000
Blasting Materials	30,000
Labor Costs	100,000
Total Cost Savings	180,000

The above Table 2 indicates the cost savings achieved with the surface mining technique as it cuts down the costs of blasts, reduced drilling expense, showing the economic advantage with the use of this technology.

Adding to this, through having longer equipment life cycle and less frequent requirements for overhaul, the RP construction company was able to reduce the maintenance expenditure and the time spent on it, which again contributed to the company's cost efficiencies (Patel and Kishore, 2016). At the end of the study using cost benefit analysis on economic modelling, it became apparent that investing in the Surface miners greatly paid up in the long run in terms of the operational productivity and costs over the useful life of the machines (Dutta, 2012). Manufacturers of coal involved in the surface mining methods witnessed an enhanced revenue position and profits margin and return on investment as compared to the ones that solely relied on conventional ways of mining.

Source: (Dutta, 2012)

Figure 1: *Comparison of Specific Costs*

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The above figure indicates that the surface mining has the least costs in each aspect, whether it is considering the operational costs, the depreciation amount, drills and even the interest costs. However, the following fact should be mentioned: the application of surface miners provides certain economic advantages in the frames of costs and production rates; nevertheless, being flat/horizontal miners, they are relatively expensive and need large investments for acquiring and applying them, which may act as limitations for certain miners, especially those of the small scale (Dutta, 2012). This may be solved through monetary innovation, fiscal any other incentives from the government or the development of symbiotic relationships that exist between mining companies and manufacturers to increase the use of surface miners in the context of the Indian mining industry.

Theme 3: Environmental and Sustainability Impact
The evaluation of the environmental consequences revealed that surface miners had the capability to counter many of the negative environmental impacts that stemmed from traditional approaches of –coal mining. Interviews carried out in the fields and data on environmental impact analysis supported the suggestion that surface miners produced less dust, noise, and vibration than drilling and blasting miners. They said that due to the accurate cutting and crushing of the surface miner, dust and air pollution was kept to a minimum.

Table 3: Environmental Benefits of Surface Miners

Environmental Parameter	Surface Miner Environmental Benefits
Dust Emissions	50% reduction
Land Disturbance	30% reduction

As sustainability is the core for every business now days, the Table 3 indicates the environmental gains attained with the surface miners, indicating a positive contribution towards sustainability and environment.

In addition to that, explosive blasting was eliminated and this also reduced the surface vibrations and any chances of getting any seismic movement which could lead to the surface sinking or ground shifting. Surface miners also created less overburden spoil pile and lower impact to the ground; therefore, they had a lower impact on the environment as compared to conventional mining methods (Yang, et al., 2021).

This study indicates that surface miners can play a role for environmental sustainability in the sectors of coal mining locations through decreasing air as well as noise pollution, soil occupation and ecological interference of coal mining with ecosystems.

However, it is still difficult to address other environmental issues that are usually as a result of surface mining namely soil erosion, water pollution, and habitat fragmentation (Yang, et al., 2021). The removal of the material and the movement of the coals using the surface miners can also affect the environment and water sources if measures are not well put into consideration. Therefore, proper encompassing environmental management measures such as revegetation measures, measures for stabilization of the soil, and water management measures are vital in reducing the impact of the surface mining so as to meet the regulatory requirements.

Theme 4: Safety Implications
The assessment of safety consequences suggested rather ambiguous results concerning the effects emerging from the presence of surface miners on OH&S status of Indian coal mines. Although surface miners do reduce fly rock, blast fumes, and ground vibrations as risks with explosive blasting, operating, maintaining and nearness dangers of equipment become some of the new safety concerns (Vingård and Elgstrand, 2013). Some of the concerns that operate with surface mining tools are; equipment failure, entrapment and fall risks which make the operators undergo through special training and protective measures.

In addition, the automation and remote operation of surface miners decrease direct communication between operators and the mining face, which lowers the possibilities of adverse occurrences. At the same time, the use of technology and equipment automation contributes to the growth of the mining process's complexity and the emergence of risks, such as cybersecurity threats and equipment failure (Vingård and Elgstrand, 2013). Hence,

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training and supervising accredited persons, as well as conducting regular maintenance of equipment, are critical to protecting the lives of workers in surface miners.

Furthermore, the forecasted integration of surface miners may also refer to the impact it will impose to the human resource in the future employment in the industry which will somehow affect the roles and responsibilities as well as the competency level need for the specific employment of coal mining. Technology implemented in surface mining promotes fresh opportunities in operating, maintaining, and servicing equipment and technical assistance positions; however, it tends to displace competent mining manpower like that required in drilling and blasting services. As such, it is possible to commendably prevent the general social repercussions of technological change on coal mines as and when required, in good terms via amalgamation of reskilling and retraining schemes, job change support services, and social safety net systems.

10) CONCLUSION

The findings about the operation, economic, environmental, and safety aspect of surface miners in Indian coal mines would be helpful. In view of the above steps of qualitative analysis and thematic synthesis in the present study, it has derived a systematic and complete understanding of performance and consequence of surface mining technology in India.

The surface miners have also shown remarkable operational efficiency in the case of surface miners, where the cutting rates, material yield, and general efficiency is much faster that in the case of drilling and blasting. These increases in efficiency coupled with the cut back in drilling and blasting materials, explosives and labour costs have been passed on by coal mining companies by reducing their expenditures. This is because while one may be required to pay a considerably large amount of capital for the acquisition of surface miners, this machine will in the long run be more profitable than its cost of acquisition.

The findings with environmental studies have shown that variabilities such as dust, noise, and the disturbance of land by surface miners have greatly reduces. It is due to these positive impacts that surface miners help the mining process in regions where they are used to be more environmentally sustainable by eliminating the possibility of the use of explosive blasting which causes unwanted ground vibrations and subsidence of the surface together with the undesirable ecological impairment of the area. Nevertheless, other environmental issues that are related to the conduct of surface operations still present some drawbacks.

Safety perspectives of surface miners have been reviewed keeping into consideration some of the solutions on how to tackle equipment operation, maintenance and proximity risks. Indeed, surface miners get rid of risks linked to explosive blasting but pose new safety risks that need actions desired to reduce. Proper training, supervision, and maintenance procedures are important to avoid falls and other related risks with workers involved with the operation of surface miners.

Thus, the application of surface mining technology has its benefits, but it is crucial to mention that there are specific problems that have not yet been solved to the fullest sometimes. Managing these challenges together with the mentioned benefits of surface mining, it will be possible to promote responsible mining in India and develop sustainable and highly resilient future for coal mining industry in the country.

Therefore, it is antithetically appropriate to perhaps conclude that the findings of this study deliver valuable fetes into the performance and growth of surface miners in Indian coal mines. From the performance and cost analysis as well as the environmental impact assessment, it can be summarized that surface miners have considerable advantages in operating costs, coal recovery rate, and environmental issues, which indicates that surface miners can become an attractive solution in future of the coal mining industry. But there are still some issues that can be seen in the aspect of initial capital investment, environmental issues, and OH&S issues. To overcome these issues more work will be needed from the industries, the mining companies, the government and other relevant actors in order to enjoy the full potential of surface mining technology and, at the same time, to mitigate as much as possible its negative consequences. All in all, the information presented in this work will help to advance the

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knowledge of surface mining activities as well as to contribute to the factors and decisions in relation to the extension of responsible and sustainable coal mining in India.

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