Chapter

Factor Analysis for Technology Management and Its Effectiveness in Indian Opencast Coal Mining

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Abstract

Coal holds utmost significance as a natural energy source propelling a nation's industrial sector growth. Besides refining coal quality through adept mine technology management, contemporary mining grapples with multifaceted challenges encompassing human resettlement, land reclamation, forest preservation, pollution abatement, and efficient logistics. The coal mining sector serves as a tangible example where technology management assumes real-world importance. Despite adopting state-of-the-art methodologies, open-pit coal mining trails global standards. India's coal industry faces persistent struggles in accessing suitable domestic coal, relying on imports despite considerable technological strides. Beyond augmenting production capacity or product innovation, technology innovation concepts empower Indian enterprises to reshape their industries. Technology management research within mining remains in its infancy, necessitating a comprehensive grasp of its implications on internal operations and strategic alignment for global competitiveness and effective technology leadership. This study aims to dissect the integral facets imperative for proficient technology management within opencast coal mining domains.

Keywords: opencast mining, Indian coal sector, factor analysis, technology effectiveness, technology management

1. Introduction

The most crucial natural energy source for the expansion of any economy's industrial sector is said to be coal. With ever-increasing industrialization, India's need for electricity generation is expanding astronomically. The use of appropriate technology is required by the changing corporate environment of today to increase productivity. Almost all industrial sectors nowadays require efficient use of technology to maintain sustainability and competitiveness [1]. From a technological perspective, the Indian open-pit coal industry is at a transitional stage. Although the government now controls the bulk of coal blocks and mines, private corporations have joined the market and are giving public-sector organizations a difficult fight [2]. Technology has become increasingly important in the age of globalization and has sped up the pace of

competition [3, 4]. Modern technology is essential for sustaining quality standards in a business environment. In the current Indian business environment, two technological components are crucial:

- Selection of appropriate technology
- Effective management and its utilization of proper technology

After pro-market reforms, technology has become the foundation of business sustainability. Technology management is a practise that involves categorizing, choosing, and implementing the technologies required to ensure an organization's continued existence and growth [5]. Despite significant investments in technology, the manufacturing sector still falls short of expectations in terms of technological performance [6]. Despite the adoption and usage of the latest technology, India's open cast coal mining industry is one of the key areas that lags behind in comparison to international standards. Modern technology is currently required by the open cast coal mining industry however, its installation and efficient administration are problematic.

From the perspective of technology management, the current study makes an effort to analyses the stated issue of low coal productivity [7]. The research makes an effort to examine many elements necessary for successful management of technology to increase the productivity of coal in CCL. It does this by using a structured questionnaire to collect primary data. The findings emphasize and carry out this effort. The study also tries to offer some guidelines for handling tools and using technology correctly and productively [8].

According to Khalil [9], appropriate technology is a suitable fit between the resources needed and the technology being used. Simply adopting new technology is a challenging endeavor because there are so many domestically and globally available alternatives. To comprehend good technology management and fully capitalize on it, the second factor has to be given greater attention [10, 11].

The notion of acceptable and inappropriate technology is shown in the image above. Any technology is appropriate at the time of development in relation to the environment for which it was created and in line with the primary purpose for which it was created. Because the environment and/or objective functions may have changed, it might or might not be acceptable at the same place at a different time [12]. Similar to this, it might or might not be acceptable at a different location at a different time, or at multiple times, depending on the surroundings and desired function. Therefore, technical appropriateness is not an inherent property of any technology, but rather arises from the context in which it will be employed as well as from the primary function (**Figure 1**).

Technology implementation and planning refers to the degree to which an organization has strategically planned the deployment of new technology(s) prior to its implementation, and the processes incorporated within this design, which influence the overall effectiveness of technology deployment and utilization. Internal planning and its implementation are a concern in the mining sector, which has an impact on coal output. Effective management throughout the implementation phase means assisting the project team, choosing the proper technology, and creating or giving the necessary training. This approach guarantees that new technology will enhance old procedures and that overall productivity will increase [14].

The manufacturing sector or industry of coal mining may be used as an illustration, where technology management can be seen as a practical problem. Open cast

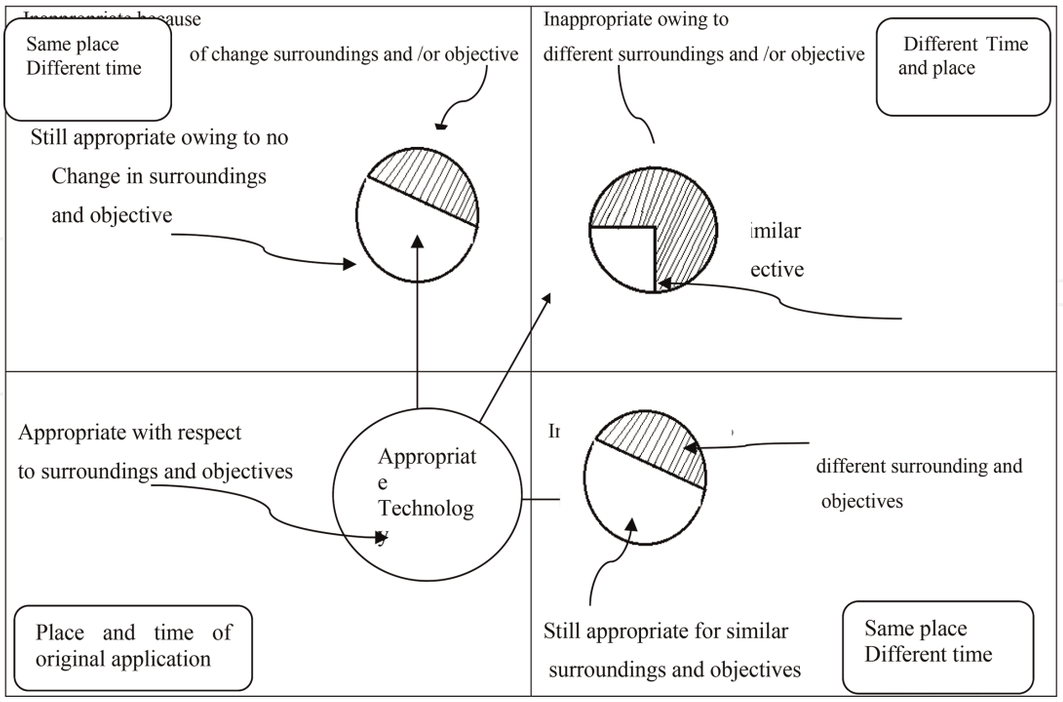

Figure 1.
Appropriate and inappropriate technologies. (Source: [13]).

coal mining employs cutting-edge technology, yet it still lags far behind in terms of worldwide standards. Despite several technical advancements, the Indian coal industry still struggles to obtain coal that is acceptable for home use rather than relying on imported coal [15]. Without suitable organizational adjustments as well as improvements in human capabilities, technology cannot be successful. Researchers believe that government-controlled coal mining enterprises lack appropriate technological management and are unable to demonstrate returns on investment (**Figure 2**).

Although technology cannot alter things on its own, it can when it is accompanied by sensible actions and well-developed human skills. There is no doubting that selecting the improper technology has negative effects on the organization's overall health, but the key is to manage technology well as well [17]. This research makes an

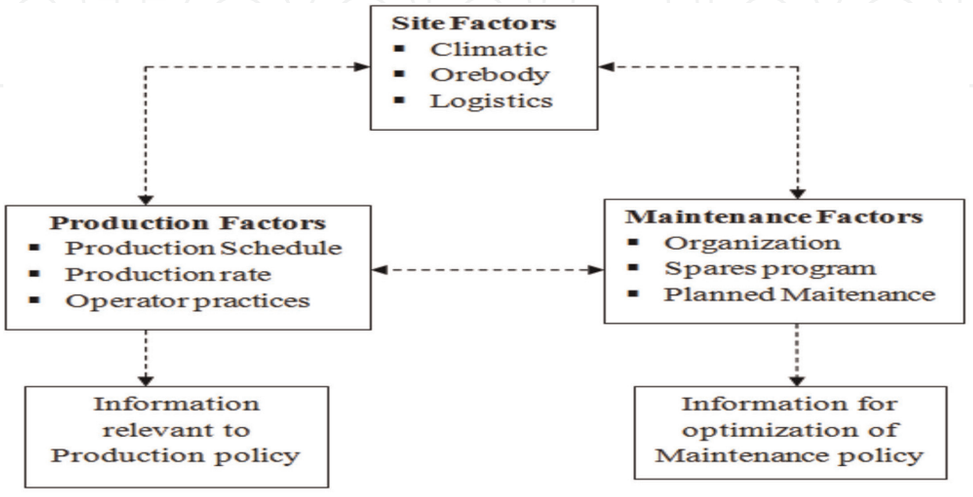

Figure 2.
Factors affecting maintenance strategies [16].

effort to identify issues related to the adoption, deployment, and effective use of the installed technology. This study's background is based on managerial concerns with regard to the efficient management of technology. One of the major public sector coal companies, Coal India Limited, together with its seven open-pit subsidiary mines and its designing division, are the subjects of the data gathering [18, 19].

This study primarily focuses on identifying the causes of the low coal productivity in CIL's seven mines, namely WCL, ECL, MCL, CCL, NCL, SECL, BCCL, and CMPDIL. This study aims to investigate the many elements needed for efficient technology management in opencast coal mining sectors. After pre-testing, reliability, and validity, the data to be collected is placed into statistical analysis, and variables affecting technology management are eventually found by utilizing Factor Analysis in Mathematical Software, i.e., Statistical Package for Social Science (SPSS) platform.

1.1 Problem identification

The most significant energy source for the production of power and for sectors like steel, cement, fertilizers, and chemicals is recognized to be coal. Therefore, the Indian coal sector requires greater investment, and private companies' active participation is also required to improve output level in order to meet the need for coal. There is no assurance that coal will be supplied at a specific quality (size, ash content, calorific value, etc.), and there are no consequences for breaking the rules either. Despite possessing a large coal deposit, imported equipment and technology, as well as a large market for coal, real coal output falls short of the desired level (**Figure 3**).

Despite having such a sizable natural coal supply, output falls short of expectations. In the open cast coal mining sector, coal is mined using HEMM (primarily drill machine, shovel, and rear discharge dumper) in combination. It is comparable to a track and relay race in which no runner competes on their own and every participant contributes to the success of the race in some way. Despite the fact that they are all on the same team, the second runner's performance in the race and his ability to successfully transfer the baton to the next team member depend on how well the first runner (the drilling machine) delivers the baton to him (the shovel). These hand-offs affect not only the next leg of the race (Rear Discharge Dumper), but the success of the entire team. And for smooth hands-off, efficiency and productivity of individual HEMM is the key. Thus, HEMM need to work in consonance with each other to optimize the productivity of the system.

The rationale can be explained mathematically as illustrated below:

Let us assume,

$$\mathrm{m} \quad \mathrm{n} \tag{1}$$

$$\mathrm{A} \rightarrow \mathrm{B} \rightarrow \tag{2}$$

$$\mathrm{At} = \mathrm{A}_0\, \mathrm{e}^{-\mathrm{mt}} \tag{3}$$

$$\mathrm{Bt} = \mathrm{A}_0 * [\mathrm{m}/(\mathrm{n}-\mathrm{m})] * \mathrm{e}^{\mathrm{mt}}-\mathrm{e}^{\mathrm{nt}} \tag{4}$$

$$\mathrm{Ct} = \mathrm{A}_0\, [1 + \{1/(\mathrm{m}-\mathrm{n})\} * (\mathrm{ne}^{-\mathrm{mt}}-\mathrm{me}^{-\mathrm{nt}})] \tag{5}$$

Here, A represents Drill, B represents Shovel and C represents rear discharge dumper. A_0 represents the initial function being performed by the drill. At represents number of pockets/holes to be drilled by the drill machine at time t. Bt

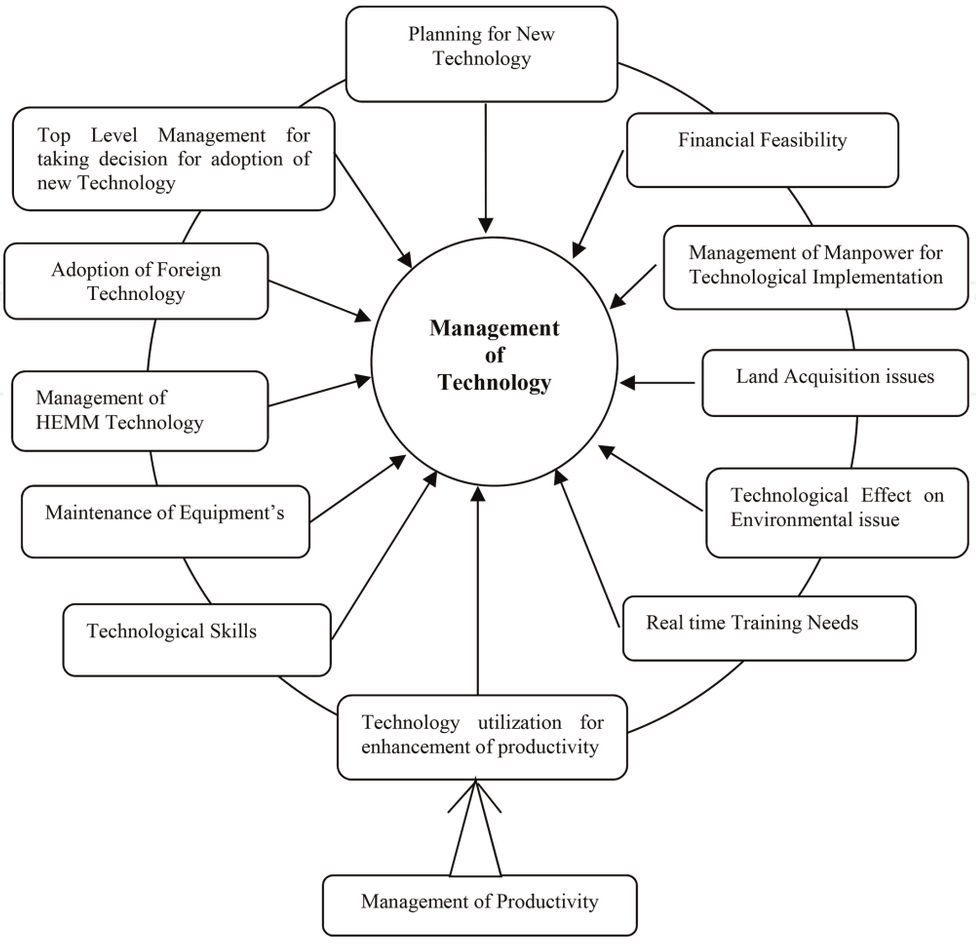

Figure 3.
Flower model with extracting variables.

represents net material available with the shovel at time t and Ct represents net material loaded on the rear discharge dumper at time t. Clearly, the net material loaded on the dumper at any time instant t depends on the kinetic factors of the drill (m), the kinetic factor of the shovel (n) and the initial material/ area available with drill (A0) The above formula is an analogous and applied version of the concept of series chemical reactions used in chemical kinetics. For the present work, three critical elements quintessential for productivity enhancement in open cast coal mining w.r.t. technology have been taken into consideration [20]. These are Drills (Element A), Shovels (Element B) and Rear Discharge Dumper (Element C) [21]. These three elements need to work in series in consonance with each other to optimize the productivity [22]. Being a series operation, individual efficiency of the predecessor constituent affects the next constituent. The net material loaded on the rear discharge dumper at any time instant t depends on the kinetic factor of the shovel (n), the kinetic factor of the drill (m) and the initial material/area available with drill (A0). Clearly, individual efficiency of the predecessor element affects the next constituent and hence the success of the system.

In order to provide appropriate corrective actions through perspective policies and suggestions, the study work raises a variety of challenges and concerns linked to managing technology and its efficacy in the coal mining sectors, namely Coal India

Limited and its subsidiaries. India ranks third in the world for coal production. It has increased coal output from 70 Mt. at the time of nationalization in the early 1970s to 355 Mt. (provisional - excludes Meghalaya) in 2009–2010 through a consistent investment programme and a stronger emphasis on the deployment of new technology. Over 81% of India's coal is produced in open-pit mines, which contribute to the country's overall production. Despite this, the industry remains unappreciated. The most significant source of energy for the production of electricity is acknowledged to be coal [23]. In addition, many small- and medium-scale businesses depend on coal for their operations and energy needs, including those in the steel, cement, fertilizer, chemical, and paper sectors. Many mining and industrial organizations look for ways to save expenses and eliminate overhead by producing more with fewer resources. The manufacturing industry has made tremendous strides in integrating new technology into its processes, including advanced manufacturing and Industry 4.0 [24, 25].

The mining sector, in comparison, is still lagging behind when it comes to integrating modern technologies into its operations. Despite such a persuasive position and demand, there are serious concerns about the output of coal from CIL. Following are some categories of plausible causes for such a poor performance [26]:

- Despite having a current fleet of equipment, production was lower.
- Inappropriate management and the use of cutting-edge technology might result in a problematic scenario. Overdependence on foreign technologies might emerge from this. It is being made worse by supplier project delays and other associated issues.
- CIL must intensify its methods for raising the quality, quantity, and cost-effectiveness needs of its clients in order to thrive in the current industrial environment.
- The indicated company's use of antiquated mining technology with reduced capacity; • Cost and time overruns caused by a lack of structural, tactical, and strategic difficulties.
- The output has also been significantly impacted by the following factors: the use of smaller fleets of trucks, conventional equipment, and shovel equipment rather than draglines and bigger sized fleets; the lack of skills necessary for adequate planning, supervision, and management; and the problem itself.
- Ineffective management and a lack of operational will have also exacerbated the issue. This problem in regard to the technology management component has also been made worse by improper and insufficient examination of the environmental, social, economic, and community implications, as well as by actual and meaningful involvement with stakeholders.
- Some of the major issues with open cast mines, such as those at the Piparwar and Ashoka mines operated by CCL, are also connected to the halting of coal transportation as a result of siding and other illegal actions.

- A lack of law and order serves as a stimulus for lower coal output.
- The difficulty in acquiring environmental and forestry clearances is delaying a lot of mining operations, and the cost and time overruns caused by a delayed clearance have made the issue of decreased production even worse.
- Surface mining necessitates the disturbance of a comparatively bigger area of land. The local biodiversity and ecological balance are disrupted as a result of numerous environmental problems like soil erosion, water pollution, and others, and occasionally local populations and environmental protection organizations also present operational challenges, which ultimately have a negative impact on production.
- Other factors contributing to the actual production of coal falling behind include inadequate drilling capacity, a backlog in overburden removal, an imbalance between excavation and transportation capacities, poor availability and under-utilization of HEMM, etc.

1.2 Need for the study

After conducting exploratory research in Coal India Ltd. following points have emerged as issues, which itself highlights the need and urge of the present study:

- Targeted production is higher as compared to actual production repeatedly has urges the need to investigate the issues.
- Despite of having the modern equipment's and technologies their management is not proper and the capacities of installed technology are underutilized.
- Preliminary data study revealed that the installed technology has little significant effect on the production and management of installed technology.
- Forgoing and nothing to bother attitude of management as well as worker.
- The urging importance of coal industry as the most important source of energy in current scenario.
- Personal interest and attraction towards the coal mining sector has also added to the need of study.
- Lack of adequacy of training programme and industrial relation policies at the selected sites of CIL.

1.3 Objective of the study

Objective of this proposed study may be highlighted and identified in the following directions:

1. To understand the importance of Managing Technology and its effectiveness in Open Cast Coal Mining Industry.

2. To find out the problems related to adoption and implementation of technology in Mining Industry that effect production of coal.

3. To determine the numerous factor necessary for efficient technology management in order to increase coal productivity.

2. Literature support: importance of technology and its effective management

Technology management is a field that combines the use of science, engineering, and management skills to fulfill an organization's technology needs. The life cycle of various technologies is handled through technology management in order to fulfill organizational goals. Understanding the value and suitability of a technology for an organization is, thus, the primary responsibility of technology management [27]. An opportunity in the market will soon end, thus a sustainable organization will try to spot it as soon as possible and take use of it for the project that must be completed quickly [28].

The effectiveness of technology also depends on non-technical factors. Non-technical variables also affect how well technology works. The same tool or machine can be operated incorrectly or correctly. The mere possession of technology is useless unless it can be handled proficiently and skilfully, which necessitates knowledge of and aptitude for industry-specific technology management [29]. Many advantages may come from managing technology, but much will rely on how those who are engaged use it. Therefore, organizations must have both management and technical experts. Technical skill is defined as the capacity of an individual to commence and finish a specific work or job using the tools and procedures proficiently [30].

Although many people are technically adept, their interpersonal skills are often lacking. Managers must possess the best possible blend of all necessary managerial skills, be able to delegate, and handle complex and contentious situations diplomatically because they are the operational and symbolic head of an organization and are responsible for tasks and results [31]. The efficient accomplishment of a well-defined set of objectives is another crucial component, which is referred to as team effectiveness. By becoming sensitive to the rapidly changing internal and external environments, successful organizations continually strive to increase the performance of their teams. This project calls for a variety of abilities and capabilities that must be supplemented among the team members. Some of the literature supports are mentioned below (**Table 1**).

2.1 Management of technology - leading variables

This study is expected to be conducted on installed technologies managed by Coal India Ltd. and its subsidiaries. Extensive literature, annual and other statistical report published by Coal India Ltd. was studied and analyzed properly to know about the leading variables involved in management of technology. It was identified that actual production of coal was below the targeted. CIL is known for its market capitalization and technological up gradations efforts but despite of this production for the considered time period was less. This has given a platform to develop hypothesis of research work in context to effective and efficient management of technology. Important

Contents	Author	Year	Remark
Knowledge of maintenance techniques is required to increase safety and output capacity in mining, and this knowledge should be based on the fields of interacting variables to maintenance.	Watson	[16]	Maintenance of overall Equipment's
Maintenance staff must get training in their specific working environment, and this training should be organized such that each employee is informed of the most recent maintenance difficulties and approaches. Safety training is crucial as part of the training requirements.	Edwin B. Flippo	[32]	Real time Training for Technical up-gradation
The operational element of the organization deals with its daily operations, whilst the planning factors concentrate on its long-term problems.	Ghatak	[33]	Operational Performance
It has been suggested that the procedures included in this design have an impact on how well technology is deployed and used overall.	Bancroft, Haddad,	[34]	utilization of technology
A process of surface coal mine planning involves selection of coal property, making decisions regarding appropriate mining method, selection of types and number of equipment's; and producing mine designs to make an optimum use of equipment's and manpower.	Steele	[17]	Planning for New Technology
The discovery and assessment of technologies, the development of new or enhanced goods and processes, the integration of technology with other business processes, and the management of change necessitated by the adoption of technologies all need complicated judgments from effective management.	Allan C. Wexler	[2]	Technological Performance
There are limitations and a number of factors that contribute to this, particularly problems with land acquisition, forest and law and order issues, as well as evacuation issues, have hampered coal production to the point where even captive coal blocks have fallen short of production goals.	Saxena	[35]	Technological barrier due to Land Acquisition
If not adequately planned and managed, mining activities cause significant environmental and ecological harm. Technology will inevitably be used to increase yield.	Boskin, M. J.	[36]	Real time Technological Advancement
The choice of technology has a significant impact on industrial growth and productivity. Technology utilization is always constrained by a goal.	Khalil	[37]	Adoption of Foreign Technology /Selection of technology is prime importance
The transformation that technology brings about must be supported by suitable organizational reforms, changes in human capabilities, and changes in training and education.	Christina Beach	[38]	Technological Skills
The management of HEMM (Heavy Earth Moving Machineries), such as the shovel-dumper combination model, aims to integrate two fundamental pieces of equipment in order to increase production and efficiency.	Ghatak. S	[39]	Management Of HEMM

Table 1.
Literature support.

inferences that can be drawn after the analysis of report present a very interesting fact that management of installed technology is affected by some factor. Technology installation is not only sufficient for organization but its effective management does matters. Pertaining to the research some variables which were important from point of view of management of technology were identified and from them factors were extracted. These variables associated with all the stages of maintenance of technology ranging from its planning stage to implementation stage. This study identified various leading variables are (**Table 2**) [40]:

After a thorough review of the literature, comprehensive interviews with shop floor managers, candid discussions with top level decision-makers within the industry, as well as initial observations and primary research, the total of 24 leading variables were found (**Table 3**).

Sl. No.	Effecting Mgmt. of Technology
1.	Planning for new Technology
2.	Selection of Indigenous Technology
3.	Selection of Foreign Technology
4.	Technological Skills
5.	Financial Feasibility
6.	Cost and Benefit Analysis
7.	Real time Technological Advancement
8.	Managing HEMM Technology
9.	Supply chain issues
10.	Waste reduction by applying new technology
11.	Real time transfer of technological change8
12.	Socio-Economic issue on new Technology
13.	Maintenance of overall Equipment's
14.	Continuous Monitoring of Quality
15.	Proper Utilization of Machines
16.	Real time Training for Technical up-gradation
17.	Safety needs for continuous technology
18.	Top Level of Mgmt. for adoption of new technology
19.	Middle Level of Mgmt. for adoption of new technology
20.	Technological barrier due to Land Acquisition
21.	Technological Effect on Environment Issues
22.	Proper Management of Manpower
23.	Market Feasibility
24.	Policy Implications

Table 2.
List of leading variables for effective Management of Technology.

Sl. No.	Effecting mgmt. of Technology	Lit. support lead by Authors'/ Practitioners'
1	Planning for Technology	Steele LW, [17]
2	Selection of Foreign Technology	Khalil, [41]
3	Selection of Indigenous Technology	Khalil, [37]
4	Technological Skills	Christina Beach, [38]
5	Financial Feasibility	Betz, Fredrick [42]
6	Cost and Benefit Analysis	Boskin and Lau, [36]
7	Real time Technological Advancement	Mehta, [43]
8	Managing HEMM Technology	Ghatak, [39]
9	Supply chain issues	Monika Maria, [44].
10	Waste reduction by applying new technology	Allan C. Wexler, [2]
11	Real time transfer of technological change	Moustafa, M. E, [45]
12	Socio-Economic issue on new Technology	Stewart, [46, 47]
13	Maintenance of overall Equipment's	Watson, [16]
14	Continuous Monitoring of Quality	Sevim & Lei, [48]
15	Proper Utilization of Machines	Bancroft, [34]
16	Real time Training for Technical up-gradation	Edwin B. Flippo, [32]
17	Safety needs for continuous technology	J. Ritson, [49]
18	Top Level of Mgmt. for adoption of new technology	Tarek Khalil, [37]; Pal et al., [50]
19	Middle Level of Mgmt. for adoption of new technology	Tarek Khalil, [37]; Koontz, [51]
20	Policy Implication	Ghatak, [33]
21	Technological barrier due to Land Acquisition	Saxena, [35]
22	Technological Performance	Singh Gurdeep, [52]
23	Proper Management Of Manpower	Chhipa et al., [53]
24	Market performance	Berman E. M, [54]

Table 3.
Literature support.

3. Coal India limited: a overview

In the industrial economy of the nation, coal has gone a long way to become one of the main sources of energy. The government took control of non-coking coal mines on January 31, 1973, and the Coal Mines Authority Limited was established with four operational divisions, including the Central Division of CMAL, which included NCDC. Further coalmine restructuring led to the establishment of CIL as the controlling company in 1975. Coal and coal products are produced and supplied by CIL and its subsidiaries to key industries such steel, power, cement, fertilizers, defense, and railways. CIL has eight subsidiary companies; details can be viewed as (**Table 4**) [55]:

Coal India Limited has acquired the status of the third largest coal producing company of the world, having its noble start in the year 1975 as a holding company,

Company	Headquarters	Year of corporation
Eastern Coalfields Limited (ECL)	Sanctoria (WB)	1975
Bharat Coking Coal Limited (BCCL)	Dhanbad (Jharkhand)	1973
Central Coalfields Limited (CCL)	Ranchi (Jharkhand)	1975
Northern Coalfields Limited (NCL)	Singrauli (MP)	1986
Western Coalfields Limited (WCL)	Nagpur (Maharashtra)	1975
South Eastern Coalfields Limited (SECL)	Bilaspur (MP)	1986
Mahanadi Coalfields Limited (MCL)	Sambhalpur (Orissa)	1992
Central Mine Planning and Design Institute Limited	Ranchi (Jharkhand)	1975
NorthEastern Coalfields Limited (NECL)	Meghalaya	1975

Table 4.
CIL with eight subsidiaries.

under ministry of coal, the company is now a maharatna company. The company is responsible for the production of 90% of the coal requirements of India. Captive Mines of TISCO, IISCO and DVC are also related to it. Coal India currently operates 510 mines and 15 washeries spread over nine states toproduce and beneficiate coal for meeting the demand of the consumers all over the country. (*Source: Coalindia.nic.in*) (**Table 5**).

3.1 Evolution of technology - coal mining industry

There are a few fundamental aspects of technology. According to Mashelkar [56], it is largely an ideational process that uses ideas to change both the material and non-material worlds. Technology is behavioral because it calls for the use of skills in both tool invention and tool usage. It is organizational and institutional since it is culturally ingrained and in opposition with the stifling institutional values. Since it is possible to combine, recombine, and change already existent technology once the process of technology has begun, it is cumulative and combinational [57]. It is a collaborative approach that incorporates social interactions and feedback loops. Technology accelerates both the problem-solving and the process. In contrast to an evolutionary process, it always enables individuals to both accomplish new things and do old ones better. The 1950s and beyond saw the development of contemporary management theories as well as organized efforts in the field of technology management (the era was distinguished by an abundance of resources for R&D).

In the 1970s, management of innovation began to operate, and the business world as a whole became interested in understanding innovation and how it should be used. However, development slowed down in the twentieth century as a consequence of the effects of global competition and the American economic crisis. Mechanical rock cutting equipment was first introduced to the opencast mining sector in the early 1980s. Lignite, coal, limestone, and gypsum were the first materials used [58]. Drilling, blasting, loading, crushing, and transportation processes are always included in traditional opencast mining operations. The effectiveness of drilling and blasting has a significant impact on the efficiency of operations. All around the nation, opencast mining searched for machinery that may help to solve these issues [59].

Sl NO	Company	2014–2015 (Mt)		2015–2016(Mt)		2016–2017(Mt)		2018–2019(Mt)		2019–2020(Mt)		2020–2021(Mt)	
		Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
1	ECL	22.57	22.20	23.18	15.74	20.34	19.74	21.75	21.83	24.20	23.20	25.19	24.05
2	BCCL	19.59	19.30	20.62	20.75	21.50	21.38	23.45	23.61	24.75	25.31	25.19	25.30
3	CCL	42.00	42.32	44.90	41.68	52.6	45.61	62.60	47.52	75.60	48.00	75.50	48.05
4	NCL	52.00	52.16	58.00	59.62	61.25	63.65	66.50	67.67	72.00	66.25	75.55	68.25
5	WCL	32.10	33.30	32.39	33.53	32.75	34.59	34.85	36.12	36.35	34.95	36.95	35.65
6	SECL	71.00	72.30	74.04	77.05	78.00	83.58	88.50	90.18	93.50	95.90	94.50	95.37
7	MCL	77.59	78.03	85.60	85.89	96.11	94.19	107.20	101.88	114.46	98.11	115.35	101.95

(Source: Project and Planning Department- CMPDIL, Ranchi).

Table 5.
Production of coal eight subsidiaries under CIL.

The advent of continuous surface miners in the early 1990s provided a solution to these issues in Europe and internationally, marking the beginning of environmentally friendly mining practises [58]. It is a practical substitute for rock breaking that does away with drilling, blasting, loading, and crushing processes. It could resolve grievances brought up by these actions. In 1993, India's first surface miner was launched as a result. In India, surface miners have been effectively used in coal and limestone mines. It has now been shown that this technology is groundbreaking for our time. The first time a surface miner was used was in the Lakhanpur opencast project, operated by Mahanadi Coalfields Limited, a division of Coal India Limited. At 2006, Central coal filed ltd. also began using surface miner at its Ashoka opencast coal mines.

The researcher had the chance to evaluate a surface miner's performance. Due to a village's close vicinity, the notion of employing or using a surface miner at mining activities was born. Over a five-year period, 700,000 tonnes of coal were blocked. The Lakhanpur opencast project's successful use of a surface miner led to better quality through selective mining and environmentally sustainable coal production. Additionally, it encouraged the commercial and public mining industries in India to employ this adaptable machinery more frequently in order to satisfy their need for coal.

Through its own conveyer boom, this machine cuts and loads coal. This machinery removes first and even secondary crushing in mineral and rock deposits as an alternative to traditional drilling and blasting operations. In situations when drilling and blasting are not feasible, surface mines are a specialized mining technique that is frequently utilized. This machine does not require drill and blast or subsequent crushing as the cutting drumps break and size rock. These machines can discharge onto conveyor belts or directly load truck or work in windrowing mode in which machines cut the material and leave the material on the floor and cut face as it to be loaded by small size front-end loader on small size dumpers for transport from mines to destination point. Generally machine requires a large area of exposed coal for efficient operation. Size of mined coal is such that further crushing is generally not required. The thin layer of coal is taken at a time, the machine is capable of cutting and loading medium hard dirt bands separately. This machine can be equipped with a sensing system to detect and identify different materials by measuring infrared radiation reflected by mineral deposits. These readings allow adjustment of cutting depth for selective mining. With use of this machine, coal washing for removing obvious dirt from R.O.M (Run of Mine) coal can be eliminated. A washery will be much costlier, both in capital and running costs, then a set of surface miners. In 1993, Piparwar project, an Indo-Australian venture has been carved out to develop a new coal mine with beneficiation plant for non-coking coal to meet the demand of power coal of consistent quality. The project is designed to achieve a very high level of productivity through introduction of Mobile Inpit Crushing and Conveying Technology in subsidiary of Coal India Ltd., i.e., Central Coal Fields Ltd. This project was started on a bilateral agreement basis. Government of India requested the Australian Government's involvement to develop the Piparwar opencast project.

3.2 Technology: innovation and its effective management

The successful use and integration of technology within an organization is crucial. A wide range of activities, data, and skills must be coordinated for project conception and execution to be successful. Due to the fact that commercial possibilities are time-

limited, an organization must move swiftly in order to take use of cutting-edge technology effectively for projects that must be completed rapidly [60]. These obstacles in the corporate environment have increased the demand for efficient technology management and control. As a result, achieving any objective, whether at the corporate or personal level, demands a methodical and carefully thought-out decision-making process. Clear objectives must be defined in order for management to function successfully or efficiently [61].

3.2.1 Maintenance of overall equipment's after adoption of new technology

Technology management is essential to maintenance work. The total of all technical, administrative, and managerial actions taken to retain or restore an item to a condition where it can carry out the required function constitutes maintenance during the course of an item's life cycle. Any form of machinery that is used requires regular maintenance and repairs. Because of the environment in which mining production systems work, safety assurance is a vital factor that must be carefully considered when dealing with operational company entities [62]. To boost safety and production capacity in mining, understanding of maintenance procedures is necessary. This knowledge should be based on the fields of interacting variables to maintenance. Some of the most important, interconnected factors that have an impact on a mine production system's reliability Watson [16].

It is evident that equipment dependability will be enhanced quickly, operating costs will be reduced, and profit maximization will be the end outcomes if these interrelated aspects are controlled appropriately [16]. In addition to exercising the necessary management and technical control of maintenance programmes, procedures and strategy are often generated from maintenance management for all maintenance-related operations. The same way that business goals are communicated to other business organizations, it is typically vital for manufacturing or production businesses to establish, develop, and communicate the maintenance strategy. Regarding maintenance practices and procedures, [63] suggested that the maintenance management process has two parts: the first is effectiveness, which primarily deals with identifying the most significant problems and potential solutions, and the second is efficiency, which deals with identification of the suitable procedures. While using a participative method, management aspirations and expectations should be kept in mind. Every organization that operates in a setting of intense competition strives to succeed by increasing its efficacy. Non-technical variables also affect how well technology works. The same tool or machine can be operated incorrectly or correctly. Technology is useless unless it can be employed proficiently and skillfully, which calls for knowledge of and aptitude in technological administration by industry [64]. However, a committed and knowledgeable team of human resources is what drives performance in an organization. On the other side, productivity is the achievement of goals via the use of resources like money, labor, equipment, infrastructure, etc. It speaks to the interaction of inputs and outputs or the effectiveness with which organizational goals are accomplished. The efficient accomplishment of a well-defined set of objectives is another crucial component, which is referred to as team effectiveness. By becoming sensitive to the rapidly changing internal and external environments, successful organizations continually strive to increase the performance of their teams. This project calls for a variety of abilities and capabilities that must be supplemented among the team members.

4. Research methodology

Standard research methodology was adopted in context to the present work. Data sources and collection methods were carefully chosen and the self-administered primary data collection tool (questionnaire) was pre validated before data collection. Observation, Interaction and interview of the respondents were another tool used in this regard. Designing questionnaire was very comprehensive; it was carefully planned and designed after identifying different variable considered important pertaining to the present study. The core items and variables in the first stage were identified after conducting extensive literature survey (Published work, Journals, Company books and Annual reports etc.). The identified factors were supplemented by another set of variables discovered and marked on the basis of personal interactions and interviews. Senior management representative, employees and expert were then contacted to verify the appropriateness of variables identified and their flow. Personal interview helped a lot in understanding views and perception of the respondents related to efficient and optimal management of the installed technology. Secondary data from syndicate source has also been considered for collecting information to specific queries.

4.1 Hypotheses testified

The technology management system used at open-pit mines. The study's findings suggest that there is an organizational framework for technology management. The production department reports to the Director (Operation), who is in charge of planning, organizing, staffing, implementing, and controlling the production process. The General Manager (Operation) of the various mines assists the Director (Operation) in developing production plans and strategies. The Deputy General Managers of various sub divisions provide support to the General Manager (Operations). Regular updates are made to the production plan to account for evolving circumstances. The revision of the production schedule demonstrates the Director (Operations)' continued confidence in long-term technological planning to guide the organization along the intended course.

H_1 = Technology is not only a panacea for increasing production rather, efficient management of technology is crucial for increasing productivity.

4.2 Factor analysis

Output of Factor Analysis is obtained by requesting Principal Components Analysis and specifying a rotation using varimax. Eigen values associated with each linear component (factor) before extraction, after extraction and after rotation. Before extraction 24 linear components were identified within the data set. The Eigen values associated with each factor represents variance explained by that linear component and also displays the Eigen value in terms of percentage of variance explained. After factor analysis total 24 variables were reduced to 12 variables and from that 3 factors that were statistically significant were identified. In this case those variable, factor loading is more than percentage of communality only that value will be extracted and rest of the variable will be dropped. After calculating the factor analysis, the variables value is VAR6, VAR14, VAR 15, VAR13, VAR21 have high loading of .969, .900, .955, .916, .933, respectively on factor 1. This suggests that *factor 1* is a combination of above 5 variables.

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.762	28.174	28.174	6.762	28.174	28.174	6.590	27.458	27.458
2	6.277	26.156	54.330	6.277	26.156	54.330	6.196	25.815	53.272
3	5.852	24.384	78.713	5.852	24.384	78.713	6.106	25.441	78.713
4	.851	3.547	82.260						

Table 6.
Total variance explained.

At this point, the researcher's task is to find a suitable phrase which captures the essence of the original variables which continue to from the underlying concept or 'factor'. In this case, factor 1 could be named as *'Mine Planning & Design'* as shown in table no. 8. Similarly, for *factor 2,* variables VAR10, VAR11, VAR23 have a high loading of .883, .889, and .986, respectively, this indicates that factor 2 is a combination of the above 3 variables. In this case, factor 2 could be named as *'Evolution of Technology'*. For factor 3, variables V1, V4, V12, V22 have a high loading of .957, .884,.966, .935, respectively, this indicates that factor 3 is a combination of the above 4 variables. In this case, factor 3 could be named ass *'Effective Management of Technology'.* Out of 24 variables only 12 variables have extracted because of Rotation Sums of Squared Loadings percentage of cumulative value is .78 and rest of variables is low loading value, i.e. it has dropped for further analysis and only 12 variables will be applicable which is statistically significant. The analysis data has given below (**Tables 6–9**):

Codes	Variables	Factor to which a variable is merged	Factor Loading	Communality
VAR01	Top Level Management	Factor – 3	.957	.926
VAR02	Middle Level Management	Factor – 3	.814	.667
VAR03	Adoption of Indigenous Technology	Factor – 3	.748	.587
VAR04	Adoption of Foreign Technology	Factor – 3	.884	.783
VAR05	Market Feasibility	Factor – 1	.712	.632
VAR06	Financial Feasibility	Factor – 1	.969	.955
VAR07	Cost and Benefit Analysis (Economic feasibility)	Factor – 1	.814	.712
VAR08	Real Time Technological Advancement	Factor – 3	.829	.717
VAR09	Continuous Monitoring of Quality	Factor – 2	.814	.731
VAR10	Technology utilization for enhancement of productivity	Factor – 2	.883	.785
VAR11	Real time Training Needs	Factor – 2	.889	.804
VAR12	Management of HEMM Technology	Factor – 3	.966	.941
VAR13	Management of Manpower for Technological Implementation	Factor – 1	.916	.857
VAR14	Land Acquisition issues	Factor – 1	.900	.814
VAR15	Technological Effect on Environmental issue	Factor – 1	.955	.939
VAR16	Supply Chain Issue & Spare Parts management	Factor – 3	.792	.698
VAR17	Minimizing Wastage by applying New Technology	Factor – 2	.857	.744
VAR18	Socio-Economic Issue on New Technology	Factor – 1	.846	.726
VAR19	Real Time Transfer of Technological Change	Factor – 2	.849	.723
VAR20	Policy Implication	Factor – 1	.929	.864
VAR21	Planning for New Technology	Factor – 1	.933	.875

Codes	Variables	Factor to which a variable is merged	Factor Loading	Communality
VAR22	Maintenance of Equipment's	Factor – 3	.935	.889
VAR23	Technological Skills	Factor – 2	.986	.975
VAR24	Safety Need for Technology	Factor – 2	.736	.549

Table 7.
Summary results of factor analysis.

Factors	Factor-1 **Mine planning and design**	Factor-2 **Evolution of Technology**	Factor-3 **Effective Management of Technology**
Variables	Financial Feasibility (V6)	Technology utilization for enhancement of productivity (V10)	Top Level Management for taking decision for adoption of new Technology (V1)
	Land Acquisition issues (V14)		Adoption of Foreign Technology (V4)
	Technological Effect on Environmental issue (V15)	Real time Training Needs (V11)	Management of HEMM Technology **(V12)**
	Management of Manpower for Technological Implementation **(V13)**	Technological Skills (V23)	Maintenance of Equipment's **(V22)**
	Planning for New Technology **(V21)**		

Table 8.
Identified leading variables under factorization for Management of Technology.

Chi-Square Tests			
	Value	**DF**	**Sig. (2-sided)**
Pearson Chi-Square	17.443	4	.002
Likelihood Ratio	18.627	4	.001
Linear-by-Linear Association		8.886	1.003
No. Of valid Cases	380		
a. 0 cells (0%) have expected count less than 5. The minimum expected count is 11.29.			

Table 9.
Test of hypothesis.

The comments provided by the chosen respondents from open-pit coal mines showed that effective management of technology is crucial to boosting coal extraction productivity. Chi-square analysis yields a value of 17.443 at 4 degrees of freedom and a P-value of. 002, which is higher than the tabulated value at. 05 in 95% confidence level, indicating that the result is significant. Therefore, the null hypothesis is rejected, and the findings indicate that efficient management of technology may be essential to boosting output. Technology can only increase an organization's efficiency; but, if it is not managed properly, the entire goal is defeated. If technology is not managed well, it will have an impact on output.

4.3 Factorization and flower model

Significant variables are identified statistically, and the corresponding factors extracted by the researcher are important pillar of the work and are highlighted below:

- Mine planning and design is first step having an indispensable effect on productivity of mine and selection of technology. In context to the stated point researcher has identified Financial Feasibility, Land Acquisition issues, Technological Effect on Environmental issue, Management of Manpower for Technological Implementation, Planning for New Technology as variables. All stated variables are important to design the layout of mine. Layout and sequencing are having a significant effect on productivity.

- Evolution of technology is second most important factor identified. Many technology options are present in market in context to enhancing productivity in coal mine but the problem lies in its effective selection and implementations. Researcher has pointed out the following variables important in this regard, Real Time Training Needs, Technology utilization for enhancement of productivity, Technological Skills. All these variables mentioned are quite important in planning and evolution of technology as a mismatch between selection and skills will result in leakages and casts a negative effect on utilization of technology and motivation of employees.

- Effective management of technology is another important aspect to be taken care of, in absence of proper management and selected technology. Capacity of installed technology cannot be utilized to the fullest and frequent breakdown and ineffective utilization may be evident in the system. Researcher has identified important variables in relation to management of technology which are technology utilization for enhancement of productivity, Real Time Training Needs.

Flower model is an intuitive approach to enhance productivity and efficiency in an integrative manner. Variables identified are complimentary to each other and are not discrete rather they are interdependent and guided towards the epicenter of management of technology. Out of 12 variables, which were found significant subsequently, were extracted in three factors namely; Mine Planning and Design, Evolution of Technology and Effective Management of Technology. These factors play a significant role in Selection, implementation and management of technology in an integrative manner and finally have a positive effect on enhancing productivity in prime sectors like coal mining.

All variables identified by the researcher represents petals of flower as the petals are joined together to the base of flower in a similar fashion these variables are coordinated, combined, interrelated and interdependent on each other to cast an incremental effect on production of coal.

5. Conclusion

Challenge in mining technologies and management for Indian mining industry is not only to improve efficiency to reduce costs but to have right time and amount set to

achieve competitive priorities most efficiently. Even though open cast mining sector is conservative, recent economic crisis has contributed to awareness that there is a wide possibility for managing technology towards effectiveness in terms of cost savings. The proposed study will successfully targeted two basic goals: firstly '*making mine operations easier*' by developing an efficient technology and second by managing in a most effective way. There are some important points should be taken care of it which is mentioned below:

- Installed technology should be properly managed and utilized in order to match the planned and actual output of coal and to increase productivity. To do this, trained employees are needed. It's also crucial to improve technological competitiveness by considering long-term planning, level of management, appropriate technology selection, land acquisition issues, technical skills, proper machine usage, and training requirements that are necessary for mining industry. Since most of the installed technology at Coal India Ltd. and its subsidiaries is imported, effective planning, selection, and implementation of the technology are required. According to the working and geophysical circumstances and factors in India, the design, technical, and operational feasibility should be carefully taken into account.

- The production of the mines would grow as a result of all these factors. To harness all the potential benefits of the installed technology its effective and efficient management is required, a properly planned and managed technology can earn and contribute to organizational performance and success. To manage the change brought on by the introduction of new technologies, effective management must make difficult but doable decisions related to the discovery and appraisal of technologies, the development of new or enhanced procedures, and the integration of technology with other business processes.

- On the other hand, productivity is not result of unit action rather it calls for combination of actions. These actions are required to create an interrelated and interdependent series to bridge the gap between planning and its effective implementation. Pertaining to the research conducted 24 variables were identified, each variable was having their unique effect on the technology installed, their usage and on their effective management. After conducting factor analysis, it was found that 12 variables were statistically significant. These variables are basically the fragments of an optimal concept called management. On the other aspect, it was concluded that target production is more than actual production because different variables (identified during study) effects management of technology and their optimal utilization. Management of installed technology is very much necessary to enhance productivity in open cast mining and after factor analysis is three extraction factors were identified under which these 12 variables were grouped. Management of technology is integration of planning, selection and implementation which is evident in the factor extracted from the variables identified. Overall analysis pinpointing that decreased production as a result of improper management of installed technology. By concentration on strategic, tactical and operational aspect, management of technology can be made efficient and further productivity on coal mining can be enhanced.

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