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INNOVATIONS OF DEEP OPENCAST MINING WITH SUSTAINABILITY

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ABSTRACT

The operating cost of mechanized opencast mines has escalated with an increase in prices of essential inputs, like materials, spares, haul-road maintenance, spiraling wages, and improved welfare facilities to employees. The Coal vision 2025 of India estimates that the total domestic coal production is projected to increase to 1086 MT in 2025, of which the opencast production will be 902 MT (83%). In India mining areas are also populated, restricting the boundaries of quarries. So quarry-bed Crusher linked to properly designed steep elevator, loading into a quarry-top bunker for truck loading or conveyor transport to the siding/consumer. A coded computer program model, in Java with cost and technical data of small quarries of a coal company, with program run **'troq'** which showed quite appreciable cost benefits with steep transport. Many other innovations are outlined and there are choices of equipment suppliers now. The research in ECL, & BCCL, subsidiaries of Coal India shows that fire and unsystematic underground mining need deep opencast mining. The objective of the paper is the continued viability of opencast mining.

KEYWORDS: Operating Cost; Cost-Benefit; Quarry Crusher; Steep Conveyor; Program Run.

1. INTRODUCTION

Mine planning and operations depend upon widely differing geological characteristics of the reserves. This research determines the cost-benefit of steep transport, operational cost details of all opencast mines of a company were collected and applied in the computer program code. India is the second-largest coal producer in the world. Output in 2019 of 783 Mt and around 90% production is from open-pit mining. Opencast reserves are getting deeper and innovations are required for sustainability and viability. Large equipment, such as draglines, power shovels, large trucks, operation costs would be different, as per project planning. CIL relies on opencast mines for 95 percent of its entire annual coal output, where Over Burden Removal (OBR) is crucial.

Use of quarry-bed crusher, steep bucket elevator, on the quarry edge, loading into quarry top bunker for truck loading, can be profitable. A quarry-wise exercise in cost saving by this method has been done, in ECL with the redeployment of surplus HEMM (Heavy Earth Moving Machinery) to new mines and converting to electrical transport. The variable design parameters in an opencast mine considered in the programming were: - reserve, grade, coal/mineral: overburden ratio, annual output, overburden removal, the gradient of seam/ deposit, number of coal/mineral and overburden benches, average distance of coal and overburden transport, etc.

Diesel prices are also escalating and so, electrical transport is encouraged Length of conveyor for a quarry could be minimized by installing a quarry-bed crusher close to the rise-side linked to a steep conveyor delivering into the quarry-top bunker, for safety against blasting and monsoon flooding leading to damage of electrical drives. The steeply inclined conveyors can bring the economic parameters of deep open pits closer to peak values. There are two basic versions of the data envelopment analysis, the Charnes, Cooper, and Rhodes (CCR) version, which covers variable returns to scale (VRS) measure.

2. Design alternatives

System dynamics (SD) is a method to dynamically describe, model, simulate and analyze complex issues and/or systems in terms of processes, information, organizational boundaries, and strategies. Very large reserves of shallow mineral or coal deposits are amenable to high production opencast mechanization and computerization of operations. While soft mineral deposits can be profitably quarried with scrapers or draglines or bucket-wheel excavators, hard deposits require blasting and consequent safety and environmental limitations are to be faced.

The economic cut-off ratio of Coal: OB and life of reserve are the main considerations for transport reorganization and techno-economics have to be worked out before taking a final decision. Quarry-bed crusher, steep bucket elevator, on the quarry edge, loading into quarry top bunker for truck loading, can be profitable. Diesel HEMM (Heavy Earth Moving Machinery) to new mines and converting to electrical transport. The HAC (High Angle Conveyor) is a sandwich belt design that employs two ordinary rubber belts on top of each other sandwiching the material between them. Specifications of the research are shown in Table 1.

Table 1: Specifications of research.

Subject area	***Engineering***
More specific subject area	*Mining Quarry Transport Management*
Type of data	*Table, image, text file, computer program, figure*
How data was acquired	*The survey, Telescopic Theodolite Zeiss, etc.; Measuring staff scaled*
Data format	*Filtered, analyzed, etc.*
Experimental factors	*Aligning steep transport against uneven quarry walls.*
Experimental features	*Matching flow from quarry bed crusher to steep transport*
Data source location	*Eastern Coalfields Ltd India with latitude 23.7053 and longitude 86.8274*
Data accessibility	*Specific data for the paper were collected by the authors by survey and measurement, refer to www.easterncoal.gov.in*
Related research article	*IT Applications in Reorganization of Quarries;* RIT 2003-National Seminar on Role of IT in the Present Scenario of Globalization, CMRI & CSI: 1-2 February, Dhanbad.

Reorganization with electricity-driven steep transport would be a boon and panacea for quarry mining. There will be greater utilization of shovels. Surplus dumpers and trucks could be shifted to new or other mines resulting in more production. There should be more OB removal, as haul roads would be solely used for the purpose. Consumption of diesel, an import item will be reduced. The cost of construction and maintenance of haul roads would minimize. Truck haulage costs can account for up to 50% of the total operating costs incurred by a surface mine. Semi-mobile in-pit crusher and conveyor systems (IPCC) can be better and traditional truck and shovel systems (TS), are compared through the cost analysis.

2.1 Computer model design: Preservation costs against system disasters are handled as direct costs and other charges consisting of profits, wages, stores, electricity, and transportation expenses are treated as indirect prices. A Computer program has been coded for finding quick results of cost-benefit with the change of the value of parameters. Since norms are not available for all the parameters, existing practical standards and approximations are used in computations, in the Java program, because of its web-centric design and easy linking together of the various programs. Apart from the price of consumables and stores, the trend of prices of HEMM is increasing. Figure-1 shows the quarry cross-section of a mine.

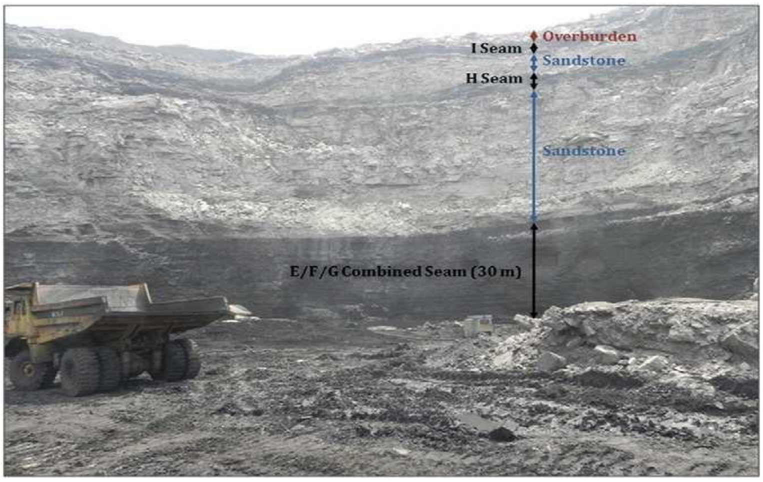

Figure 1: Block 4 Quarry Edge.

At first, the program layout, algorithm, and then flowchart have to be delineated, before writing the source program. The compiler provides a Processor, which replaces defined identifiers with codes, conditional selection of the file codes, the inclusion of other files, and renumbering of source file lines and renames the file. The package is a collection of classes and interfaces. The variables taken into account are the life of mines, number, type, capacity, and price of shovels, dumpers, transport trucks, etc. Multiple objectives consist of production, cost, revenue, labor productivity, and machine productivity. The layout comprises of crusher, bucket elevator, and bunker with a screen for steam and slack coal. Long-term production scheduling optimization for surface mining operations could be done with an application of the Minimax or other Scheduling Software. Saving in dumper/truck cost could be high, as coal transport dumpers or trucks will be moving in quarry beds mostly and trucks need not climb up haul-roads and more turn round could be there.

3. Related possibilities

3.1 High bench technology: One of the ways to significantly improve the technical and economic performance of open-pit mines in the transition to high (up to 30-35 m and more) bench stripping with the use of new extraction-and-loading equipment. it is necessary to justify the optimum layer height for various equipment complexes according to a minimum of the total operating costs of three interrelated processes - drilling and blasting wells, excavating and loading, transportation of the rock on the pit bank.

3.2 Pipe conveyors for coal transport: The pipe conveyor is an enclosed curve-going transportation system for all kinds of bulk materials. At the loading and discharging points, the conveyor system is identical to open troughed conveyors. The open belt passes through a series of transition idlers to form a pipe shape, which is maintained for the length of the conveyor. Just before the discharge pulley, the belt opens again[10] and allows the material to be discharged in the normal fashion. On the return side, the belt is again formed into a pipe shape. Due to its tubular shape, the conveyor can manage horizontal and vertical curves as well as high inclinations.

3.3 Truck lift systems: The truck lift slope hoisting system which considerably accelerates and cheapens transport from the mine.[11] While the trucks move upwards at less than 3 m/s on a slope of 10 % at the maximum, a slope hoisting plant can overcome the mine's natural angle of repose of over even 50° at 8 m/s.

4. Program details

The flowchart of the model program troq is shown in Figure 2 and the Algorithm is shown.

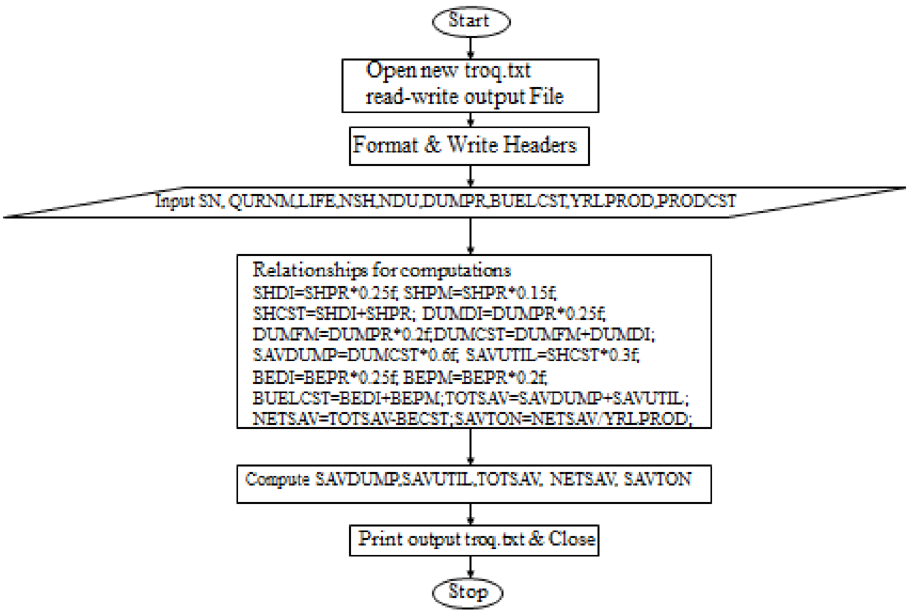

FIGURE 2: FLOWCHART OF PROGRAM FOR QUARRY REOGANIZATION

**Algorithm of troq/ ***the Model Program for Quarry Reorganization

Step 1: Start Model Program for Calculation of Economy of Transport Reorganization in Quarries declare variables

Step 2: Open new output File "troq.txt", for read-write; write headers

Step 3: SN| QURNM |LIFE|SHOVEL DETAILS|DUMPER DETAILS| SAVDUMP| SAVUTIL|TOTSAV|BUELCST|NETSAV|YRLPROD|PRODCST|SAVTON|

Step 4: Relationships for computations

SHDI=SHPR*0.25f; /* SHDI- Yly Shovel Dep∬

SHPR- Total Shovel Price /* DUMPR- Tot Dumper Price

SHPM=SHPR*0.15f; /* SHPM- Yly. Shovel Power/Fuel & Maintenance

SHCST=SHDI+SHPR; /* SHCST- Yly. Shovel Cost

DUMDI=DUMPR*0.25f; /*DUMDI- Yly. Dumper Dep∬

DUMFM=DUMPR*0.2f;/*DUMFM- Yly. Dumper Fuel & Maintenance

DUMCST=DUMFM+DUMDI; /* DUMCST- Yly. Total Dumper Cost

SAVDUMP=DUMCST*0.6f;/* SAVDUMP- Yly. Saving in Dumper Cost

SAVUTIL=SHCST*0.3f; /* SAVUTIL- Yly. Gain in Shovel Utilization

BEDI=BEPR*0.25f; /* BEDI- Yly. Bucket Elevator Dep & Int;

BEPR- Bucket El. Price

BEPM=BEPR*0.2f; /* BEPM- Yly. Buck. Elev. Power & Maintenance

BUELCST=BEDI+BEPM; /* BECST- Yly. Buck. Elev. Cost

TOTSAV=SAVDUMP+SAVUTIL; /* TOTSAV- Yly. Total saving in Cost

NETSAV=TOTSAV-BECST; /* NETSAV- Yly. Net saving in Cost

SAVTON=NETSAV/YRLPROD; /* SAVTON- Yly. Net Saving per Tonne.

Step 5: SHOVEL DETAILS: |NSH- No. of shovels| SHPR | SHDI- Shovel Dep+Int | SHPM | SHCST

Step 6: DUMPER DETAILS: |NDU- No. of Dumpers| DUMPR | DUMDI- Dunper Dep+Int | DUMFM | DUMCST|

Step 7: Input Quarry Name: "); QURNM

Step 8: Input LIFE in Yrs: "); LIFE

Step 9: Input SHOVEL No: "); NSH

Step 10: Input DUMPER Price in Rs. lakhs: "); DUMPR

Step 11: Input BUCKET EL Cost: "); BUELCST

Step 12: Input Yearly Prod in lakh Tonne/Year: "); YRLPROD

Step 13: Input Production Cost Rs / Ton: "); PRODCST

Step 14: Compute SAVDUMP|SAVUTIL|TOTSAV| NETSAV| SAVTON|

Step 15: Print troq.txt file and close

When the program ran, one by one data is entered of mine name, life, no with the capacity of shovels, no. of dumpers, depreciation, and interest, fuel and maintenance, dumper, cost, truck cost, conveyor length, depreciation, and interest, power and maintenance and yearly production.

Then, considering depreciation and interest @ 25% per year, fuel and maintenance, actual cost, etc., operating dumper/truck cost is determined in ₹ million/ year. There are enough reserves of power-grade coal, ores, and minerals to last more than 200 years, as compared to petroleum reserves of India, which are likely to last less than 40 years. Saving in utilization is expected to be around 30%. Thus, total saving in dumper and truck cost is computed from which Bucket Elevator cost including depreciation and interest, power, and maintenance is deducted to arrive at a net saving in ₹million/ year and also in ₹/t is computed, which in turn represents cost-benefit possible after transport reorganization. The names of the mines are deliberately coded, as the cost figures are confidential. The cost of different items has been computed from data of operating mines of a coal company in India. So, the output of the computer program should be fairly realistic, subject to the constraints mentioned earlier. Profit or loss P/L = (b-a) D_a- F, where, F- fixed cost, b- ₹/Km., a- variable cost, D- Break even distance, D_a - actual distance km., D = 239 to 1126 P/L =1,095 –2206 ₹/km.

As was observed from the program run output, accrued savings ranged from Rs.40.10/t, in the RJ-RJM mine to Rs.1175.62/t in the MU-SHP mine. Many other small variables have been discounted and realistic saving could be less. But irrevocably the fact stands out that there is considerable justification in reorganization to electricity-driven vertical transport in opencast mines, especially small mines.

Only 1 mine in the study, for example, SD-SLD were produced with hired dumpers/tipping trucks from quarry bed to surface. But contractual payments and hiring charges are included in the cost. Therefore, we find that although the production cost is high due to other reasons, yet there is a projected gain on the introduction of steep transport. Analysis of rock properties at the slope of the opencast mine should be done for stable anchoring of the Steep Elevator.

5. CONCLUSIONS

The various other aspects of the implementation of an opencast coal project, like organizational structure, construction, planning, monitoring and control, material management, contract management, mine development, infrastructure, ancillaries, manpower, recruitment and training, environmental management, etc. have to be ensured adequately. Salient points of steep transport model program **'troq'** developed are: -

- Cost-benefit computed in the model program run Table No.-5 was found very high.
- Increased profitability and better performance of opencast mines, coupled with saving in foreign exchange due to less import of petroleum products.
- State Governments are liberally granting mining leases to private and even to foreign companies.
- Deposits in patches and under shallow cover and so amenable to the method
- Computer program output, the cost of production can be reduced.
- The application of a Steep transport/Pipe Conveyor would be profitable

Digitally signed and encrypted e-Tenders on a Percentage Rate basis are invited under the Single Cover system on the website from the reputed and experienced contractors for the described work. In case of payment through Net-banking the money will be immediately transferred to the company designated Account. The bidders will have to accept unconditionally the online User Portal Agreement, which contains the acceptance of all the Terms and Conditions of NIT including General and Special Terms & Conditions.

Many manufacturers have brought out steep transport systems like METSO, India Mart, FLSmidt, FLEXOWEL, Dynatec, Kesnercz, and so on. Based on this study small quarry owners can utilize according to the conditions of the mine. One of the ways to significantly improve the technical and economic performance of open-pit mines in the transition to high (up to 30-35 m and more) bench stripping with the use of new extraction-and-loading equipment. The real distribution function for the uncertain parameters can be defined by gathering real data of a mine for running a more practical model. With leveling and filling material with favorable (stronger) geotechnical characteristics, improved driving conditions and maintenance of transport routes in the mine can be obtained. Costs for transportation of coal, when using the haul road-conveyor transport or hoister was found more economic.

Based on the cost-saving projected, by model program run of 'troq', scheduling for transport reorganization of quarries should be prioritized. When the deep quarry starts losing, high-capacity high-wall mining, below the can be adapted. The demand for such equipment could be high and Indian machinery manufacturers could gain in the long run.

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REFERENCES

1. Fedotenko Viktor and Ekaterina Esina: Substantiation of the Technology of Efficient Transition to High Bench Stripping of Thick Coal Seams, *IIIrd International Innovative Mining Symposium*, 2018. https://doi.org/10.1051/e3sconf/20184101044.
2. Molodykh S.S, Ovsyannikov M.P, and Petrunin A.M.: Outlook on the Implementation of Steep Inclined Conveyors in Deep Open Pits, *International Journal of Advanced Research in Engineering and Technology (IJARET)*, 2020; 11, 5: 374-377. ISSN Print: 0976-6480, DOI: 10.34218/IJARET.11.5.2020.039 © IAEME Scopus Indexed.
3. Samanta BK: Coal Project Responsibility Scheduling Model, *International Journal of Engineering Trends and Technology (IJETT)*, February, 2017; 44 (4): 146-152 ISSN:2231-5381. www.ijettjournal.org.
4. Mahapatra B, Bhar C, and Mondal S: Performance Assessment Based on the Relative Efficiency of Indian Opencast Coal Mines Using Data Envelopment Analysis and Malmquist Productivity Index, Department of Management Studies, Indian Institute of Technology (Indian School of Mines), *Energy, 2020.*
5. Marco de Werk, Burak Ozdemir, Bellal Ragoub, Tyrrell Dunbrack &Mustafa Kumral: Cost analysis of material handling systems in open pit mining: *A case study on an iron ore pre-feasibility study*, 2016; 2: 369-386. doi.org/10.1080/ 0013791X. 2016.1253810
6. Samanta BK: IT Applications in Reorganization of Quarries, *National Seminar on Role of IT in the Present Scenario of Globalization, CMRI & CSI*- 1-2 February, 2003.
7. Manas Mallick, Bhanwar Singh Choudhary, G Budi: Long-term open pit mine production scheduling with a variable cut-off grade for cost optimization, *Journal of Mines, Metals & Fuels*, [Index in SCOPUS], 2020; 68, 5: 153-157.
8. Nurić Adila, Nurić Samir: Numerical modeling of transport roads in open-pit mines, *Journal of Sustainable Mining*, 2019; 25-30.
9. Samaddar AB, Samanta BK: Formulation of Coal Mining Projects by Expert System, *Journal of Mines, Metals and Fuels*, June, 2002, ISSN 0022-2755, 202.

10. Abbaspour H, Drebenstedt C, Badroddin M, Maghaminik A: Optimized design of drilling and blasting operations in open-pit mines under technical and economic uncertainties by system dynamic modeling, *International Journal of Mining Science and Technology*, 2018; 839–848.
11. Barnwood Lars, Lottermoser Bernd G: Identification of digital technologies and digitalization trends in the mining industry, *International Journal of Mining Science and Technology*, 30: 747–757. DOI: 10.1016/j.ijmst.2020.07.003, ISBN: 2095-2686.
12. Biswaranjita Mahapatra, Chandan Bhar and Sandeep Mondal: Performance Assessment Based on the Relative Efficiency of Indian Opencast Coal Mines Using Data Envelopment Analysis and Malmquist Productivity Index, *Energies, 2020.*
13. Chanda E K, Ricciardone Jacob: Longterm Production Scheduling Optimisation for a surface Mining Operations, An Application of the Minimax Scheduling Software; *International Journal of Surface Mines, Reclamation & Environment*, 2001. DOI: 10.1076/ijsm.16.2.144.3400, ISBN: 1389-5265.
14. Chris Ross, David Conover, Jake Baine: Highwall mining of thick, steeply dipping coal–a case study in geotechnical design and recovery optimization, *International Journal of Mining Science and Technology*, 2019; 29: 777–780. DOI: 10.1016/j.ijmst.2017.12.022, ISBN: 2095-2686.
15. Kumar Peeyush: Innovative Technologies for the Growth of Coal Sector,*7th Asian Mining Congress, MGMI*, Kolkata, India, 2017; 8-11.
16. Kuzmenko S, Kaluzhnyi Y, Moldabayev S, Shustov O, Adamchuk A, Toktarov A: Mining of Mineral Deposits, 2019; 13(3): 104-112. ISSN 2415-3435; https://doi.org/ 10.33271/ mining13.03.104.
17. Sahu V, Dewangan P, Mishra R, and Jhariya DC: Opencast Coal Mining at Large Depth in India challenges Ahead, *World Journal of Engineering Research and Technology* WJERT, ISSN 2454-695X, 2017; 3, 3: 201 – 211.
18. Satyanarayana Inumula, Sinha Ashim Kumar: A Critical Review of Stability Analysis and Design of Pit Slopes in Indian Opencast Coal Mines, *Chemical Engineering Transactions*, 2018; 66. ISSN 2283-9216, DOI: 10.3303/CET1866206.
19. Nguyen-Thoi, Jian Zhou & Jie Dou: Prediction of slope failure in open-pit mines using a novel hybrid artificial intelligence model based on decision tree and evolution algorithm; Scientific Reports, 2020; 10: 9939 | https://doi.org/10.1038/s41598-020-66904-y.
20. Sengupta, S., Subrahmanyam, D. S., & Sinha, R. K: State of ground stress its use and measurement in rock engineering with special reference to weak rocks ISRM (India)

Journal, 2014; 2(1): 11–29, 3, 2. ISSN: 2277-131X. www.nature.com/ scientificreports/Xuan-Nam Bui, Hoang Nguyen, YosoonChoi, Trung