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Strategies to Improve Operations in a Complex Underground Project

Binay Samanta[1]*, Ram Narayan Som[2] and Mohammed Jawed[1]

[1]*Department of Mining Engineering, Indian Institute of Technology, Indian School of Mines, Dhanbad, India*

[2]*Eastern Coalfields Ltd, General manager, India*

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***Corresponding author**: Binay Samanta, Department of Mining Engineering, Indian Institute of Technology, Indian School of Mines, Dhanbad, India

Abstract

Mining is the most dangerous peacetime profession in the world, so safe and productive technology is needed for viability. Underground mining sustainability is on the wane, because of environment, ventilation, support legislations resulting in poor productivity. Longwall mining is a highly productive underground coal mining technique, provided very large area with undisturbed roof is available. Being highly capital-intensive Longwall Power Supports System (LWPS) as well as Continuous Miner System require project and operation management to be inter-linked. Jhanjra mine of ECL, a subsidiary of Coal India Ltd was started and target production of coal was slipping, and critical studies were made by the authors. Although, Coal India is in Public Sector, private shareholders have invested, and so business viability is needed. Operation management and monitoring of the project was done over a year and critical appraisal is presented based on investigations.

Keywords: Equipment Selection; Rock Mechanics; Longwall Mining; Continuous Miner; Operation Monitoring

Abbreviations: LWPS: Longwall Power Supports System; NPV: Net Present Value; RSR: Rock Structure; Rating RMR: Rock Mass Rating; ESR: Excavation Support Ratio; ESDL: Equipment set of Side Discharge Loader; ELHD: Load Haul Dumper ECHMN: Continuous Miner; ELWPS: Longwall Shearer with Power Support; CIL: Coal India Limited; MARC: Maintenance and Repair Contract; SPI: Schedule Performance Index

Introduction

One fifth of the world GDP more than $12 trillion will be spent on projects every year till 2020. Latest developments in Project Management as outlined in ISO 21500 have been utilized in this paper. As per International Energy Outlook, India requires 821 Mt of coal production by 2020. Choice of equipment for underground coal mining is for coalface mechanization, with appropriate selection needed. The success of coal face equipment is primarily dependent upon coal production, close to rated capacity and then ventilation, transport, lighting, dust control, quick erecting supports, condition of roof and floor etc. Various models and designs with different loading capacity are available, but the models found quite successful in Indian conditions have been taken into consideration with actual costing data. Once project parameters are finalized, regular scheduling and monitoring is required to improve project performance. DCF-based methods are likely to remain a dominant valuation tool for mines with what they call "healthy" cash-flows. In a general form, DCF and the closely related concept of net present value (NPV) can be written as a function of project [1] cash-flows (revenues minus operating costs) and the initial investment: Theoretical background $DCF = \sum CFi\ (1+r)\ i\ n\ i=0$ (1) $NPV = \sum CFi\ (1+r)\ i - I0\ n\ i=0$ (2) where CFi is the cash-flow (revenues less costs) for year i, I0 is the initial investment and r is the discount rate representing the risk. Appropriate discount rate can be estimated [2] on the basis of similar (type of) investments. Often a company-specific weighted average cost of capital (WACC) is used as the discount rate, but a correct risk-corrected discount rate specific for project cash-flows should be used.

Choice of Equipment

The authors have designed a model program for determining the right equipment for a particular mine, depending upon geological and other parameters. Program run displays most economic underground mining for the reserve. Cavability Index [3] of overlying roof depends upon thickness, massiveness, and strength parameters. As per tests in CIMFR, Cavability Index of easily cavable roof is 2000, moderately cavable-4000, cavable with difficulty-6000 and above. Test of coarse-grained coal-measure sandstone [4] has RQD-86%, Comp.Strength-480, Tensile strength-44, Shear Strength- 80 kg/sq. cm and it is observed that RQD is very close to Shear Strength value. There are several rock properties and shear and tensile strength is roughly 6-10 times

less than the compressive strength of coal-measure rocks. Various researchers have used different rock properties [3] like RQD% (Rock Quality Designation) developed by Decre, Protodeakonov Index (1-7), Moduli of Elasticity (2-7*10000 kg/sq.cm), Creep properties etc. Rock classification by Tergazhi or Lauffer is mostly based on structural defects like spacing, condition and orientation of joints. RQD ranges from less than 25% for poor rocks and more than 80% for excellent rocks. Rock Structure Rating (RSR) range from 6 for soft rocks to 30 for very hard rocks and for Indian coal-measure rocks RSR is 20-25. Rock Mass Rating (RMR) ranges from 15 for very poor rock to 80 for very good rock. Excavation Support Ratio (ESR) is 3-5 for temporary mine [5] openings and 1 for rail or road tunnels.

A computer program was designed, with algorithms and coded in Java, compiled and run for the purpose. The model program 'eqp' along with the subroutine, selects equipment type with inputs of Shear Strength of roof stone, coal, floor stone, thickness of coal seam, size of largest faultless panel. The eqp.java is the source file, [6] and eqp. cls is the compiled file. The program has considered 4 types of equipment packages, most commonly used in Indian coalmines, namely Equipment set of Side Discharge Loader (ESDL), Load Haul Dumper (ELHD), Continuous Miner (ECHMN) and Longwall Shearer with Power Support (ELWPS). Figure 1 shows the Flowchart of the program for selection of Underground Equipment. The variable names have been declared with codes and data types-namely SLNO, COLLIERY, COE (Cost of Equipment). The cost of equipment has been shown with switchgears and declared in DATA statement, in Rs. Millions-ACNV (Armored Conveyor), BCNV (Belt Conveyor), CCNV (Chain Conveyor), The input data file has been named eqp.dat and its header is formatted, as per statement 5. The Run file is named eqp.txt and the header is formatted as per statement 10. Input of data has been according to actual cost figures and so there is great variance, but the names of the collieries are deliberately coded. The result of choice of EQTYP by the subroutine is fed to the main program, which then calculates cost of equipment on the choice of equipment. Table 1 shows data input file from ECL with names of mines coded in the 'eqp' program. Table 2 displays the output file of the program shows that price benefit was low in Longwall and Continuous Miner methods, compared to SDL and LHD. But later studies show Continuous miner set is the most economic, because Longwal [7] require undisturbed roof over the entire district apart from high capital cost.

Table 1: Input Data – EQP. Dat File.

SL No	COLLIERY	CP	POC	POC	SC	WC	OC	SSR	SSC	CST	SSF	LFP
1	BKL/BKL	437	1	61	75	152	73	120	40	3	110	200
2	CHR/KND	480	2	60	68	178	98	140	35	7	90	300
3	CHN/SOD	475	1	97	81	165	87	140	19	4	75	600
4	DHM/STP	450	1	94	82	130	115	90	25	3	75	2000
5	JRA/JHR	411	9	65	76	125	124		430	4	78	2500
6	NSR/KNT	464	1	83	91	138	74	115	45	3	125	300
7	PRS/KNT	472	1	75	84	154	79	130	70	4	130	400
8	BHL/KND	490	1	81	95	154	92	140	40	3	145	450
9	DBS/SDP	485	1	93	82	149	91	135	85	4	125	350
10	KLD/SAT	436	1	60	50	148	10	125	50	3	105	250

Table 2: Program Run Economic Equipment Package.

SLNO	COL-LIERY	EQUIP	COST	PRODN	DE-P&INT	POWER	STO-RECOST	WAGECST	OTHCST	PRD-COST	PRICE	BENE-FIT
		TYPE	EQPT	COALLT-PY	YLYR-SPT	+MNTR-SPT	RSPT	RSPT	RSPT	RSPT	RSPT	YLY
1	BKL/BKL	ESDL	45	1	9	61	75	152	73	370	437	67
2	CHR/KND	ELHD	70	2	7	60	68	178	98	411	480	69
3	CHN/SOD	ECNMN	49	1	10	97	81	165	87	440	475	35
4	DHM/STP	ELWPS	175	7	5	94	82	130	115	426	450	24

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5	JRA/JHR	ELWPS	175	9	4	65	76	125	124	394	411	17
6	NSR/ KNT	ESDL	45	1	9	83	91	138	74	395	464	69
7	PRS/KNT	ESDL	45	1	9	75	84	155	79	401	472	71
8	BHL/ KND	ESDL	45	1	9	81	95	157	92	434	490	56
9	DBS/SDP	ESDL	45	1	9	93	82	149	91	424	485	61
10	KLD/SAT	ESDL	45	1	9	60	51	148	105	373	436	63

Fast Tracking Longwal Project

Critical review of a Longwal Project over 4 years with detail tracking with MS-PROJECT has many interesting revelations. Modern techniques [6] are used in optimizing the project rescheduling. Table 3 shows the summary of Jhanjra Combined Underground Project. The result of optimization provides essential information of management and [8] decision-making for engineers and workmen. Jhanjra Combined PR was revised at 3.50 MTY with capital investment of Rs.602.86 Crores, as approved on 03.05.2016 by Board of Directors of CIL. Jhanjra Combined UG had major activities of

a) Finalization of global tender for supply of package on hiring basis done in March 2017.

b) LOA for supply of LHCM on hiring basis issued on 29.08.2016.

c) Commissioning of PSLW equipment and start of production.

Table 3: Jhanjra Combined U/G Project.

Project Profile	As Per PR
Target Capacity (Mty.)	3.5 MTY
Capital Outlay/Expenditure (Rs. Crs.)	602.86
Date of sanction	PR approved by 283rd ECL Board on 30.09.15a nd by 322nd CIL Board on 13.11.15 & 326th CIL Board on 3.5.16.
Location	Project is located in the N-E side of Raniganj Coalfield. I t lies between latitude 23°38'22" N to 23°41'41" N and Longitude of 87°16'42"E to 87°20'55"E. It is about 5 KM from Ukhra Railway Station of the ER.
Duration of construction (Years)	2
Schedule date of completion	31.03.2022
Manpower (Ultimate)	2656
OMS	5.31
Mineable reserve (mt.)	28.36
Life (Years)	12
Grade	R-VI: G4, R-VII & R-VIIA : G-5
Cost of production (Rs. /t)	Rs. 2077.46 /Te at 100% production level & Rs.2276.17/ Te at 85% production level.
Profit (Rs. /t)	Rs. 1306.86 /Te at 100% production level & Rs.1108.15/ Te at 85% production level.

Considering the various operational constraints, liquidation of upper seam, delay in availability of land for caving etc. action has been taken to improve underground production mainly by introduction of mass production technology deploying Continuous Miner with Shuttle Car in more number of underground mines in XII Plan like Jhanjra. Commissioning was expected to be completed in December-2017. Contract for supply and operation of Jhanjra R-VI Seam had been signed on 8th January 2013. Commissioning has been done in August-2016 and production started from 18.08.2016. In India approval of coal projects is very long process and displayed in (Figure 1).

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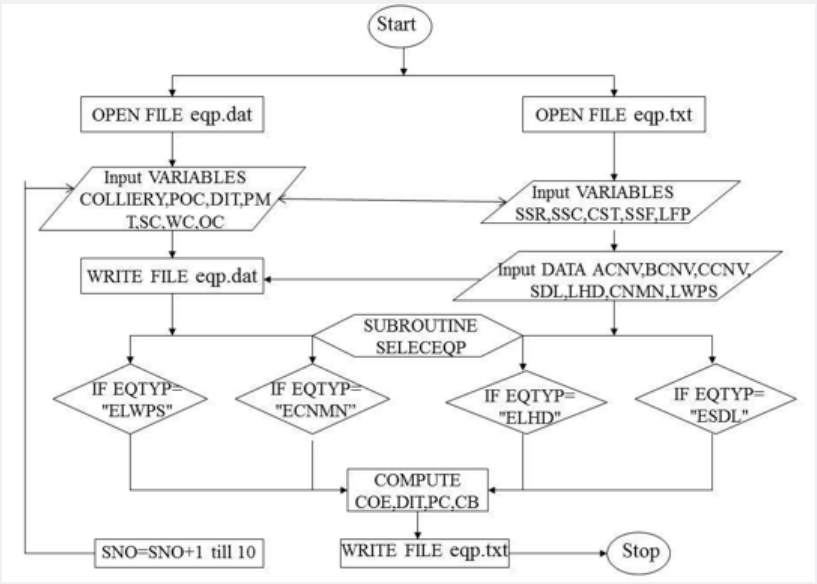

Figure 1: Selection of Underground equipment.

Materials & Methods

Financial Plan was made listing the expenses and quantifying the financial schedule. Quality Plan was decided with the quality targets and assurance of control process. Risk Plan was done by identifying the risks, prioritize them with management process. Communications Plan was revised with Situation Analysis, objectives, guidelines, and matrix. Procurement Plan was done [9] by identifying the procurement requirements, researching the market offerings and by streamlining the procurement process.

The organization structure at the mine is headed by the General Manager, with direct reporting from the all operational and administrative departments. Employees working in hazardous areas are trained to minimize any physical and chemical risks. The training programs included preventative and emergency measures to deal with the effects of the hazards. On being conferred the 'Maharatna' status, Coal India Limited (CIL) is now empowered to sanction/approve and implement all its projects including those which are beyond the delegated powers of the Boards of its subsidiaries. The purpose of the study is to reschedule the activities of the project, for bringing completion date of project, without time and cost over-run. Jhanjra Project schedule was done by entering details of all activities and packages in MS-Project at start of study in October 2018. The program run of all activities is spread over several pages and display of first page screenshot is in Table 1 given below. The total schedule of Jhanjra Project runs in 10 sheets and for exemplification screen print of the first page of MSPROJECT format is shown.

Dependencies

Dependencies are logical relationships between processes, activities or tasks that influence the way in which a project was undertaken. They were either internal to the project (e.g. between project activities) or external to the project (e.g. a dependency between a project activity and a business activity). For efficient management, activities were grouped in packages with responsibility assignment.

Critical Path Analysis

Despite large reserves, production growth has been well below growth in consumption. Some of the activities of Jhanjra Combined underground Project are as given in Table 4.

Fast-tracking Critical Activities

Activities having floats in critical path have to be crashed even with additional cost to achieve target date of completion of project. Finding the Critical Path, then it is known, which activities will affect the project deadline. When decided to crash a project, must add resources to one of the activities on the critical path. Focus is to reduce the number in the duration activities, referring to real-time to completion of that activity and not working hours. Working hours may actually go up while crashing a project because new resources will need time to get up to speed. Attention was paid on:

a) A larger activity that can support more resources

b) A fairly common activity that doesn't require high specialization

c) A task that can be completed modularly

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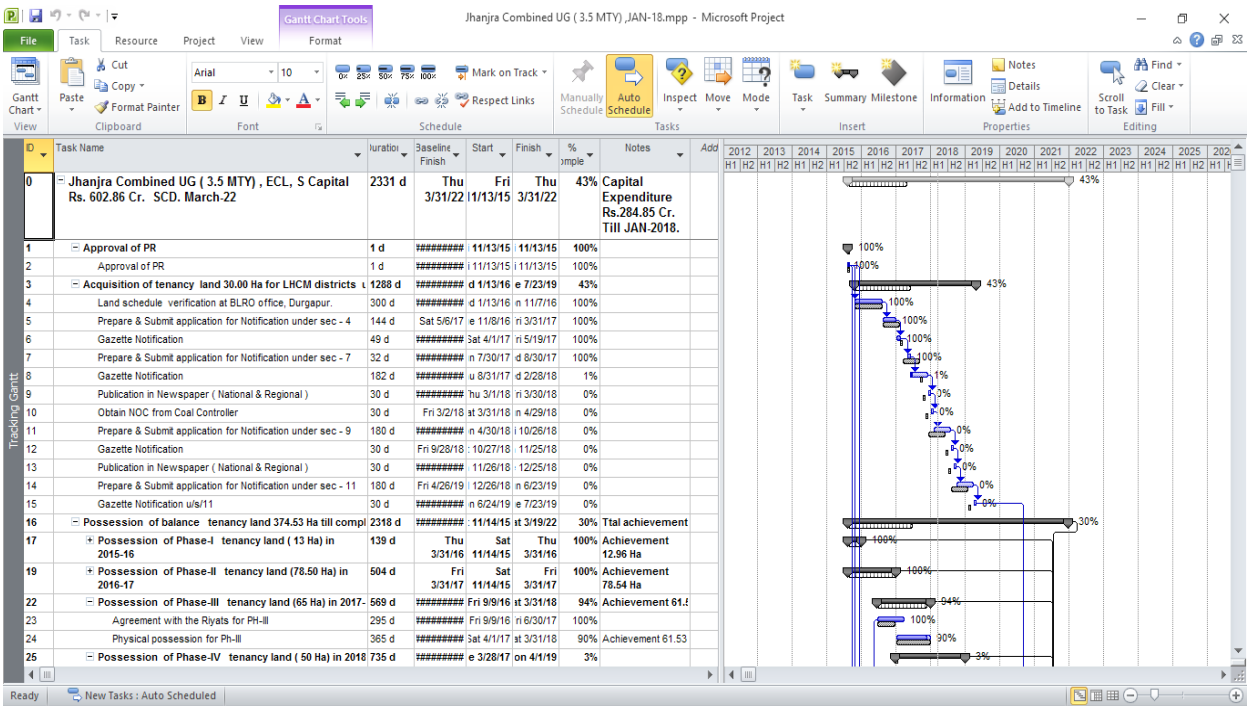
Open communication with the team to make them aware of the change and why it is happening, especially to the person whose activity is being crashed. The cost chart could be linear or non-linear depending upon execution. Crashing here means reducing the duration time model program of the activity model program in the path, even at higher cost is profitable in the long run, as shown in Figure 1.

Table 4: Jhanjra Schedule.



ID	Task Name	Duration	Baseline Finish	Start	Finish	% Complete	Notes
0	Jhanjra Combined UG (3.5 MTY) , ECL, S Capital Rs. 602.86 Cr. SCD. March-22	2331 d	Thu 3/31/22	Fri 11/13/15	Thu 3/31/22	43%	Capital Expenditure Rs.284.85 Cr. Till JAN-2018.
1	Approval of PR	1 d	########	11/13/15	11/13/15	100%	
2	Approval of PR	1 d	########	11/13/15	11/13/15	100%	
3	Acquisition of tenancy land 30.00 Ha for LHCM districts	1288 d	########	1/13/16	7/23/19	43%	
4	Land schedule verification at BLRO office, Durgapur.	300 d	########	1/13/16	11/7/16	100%	
5	Prepare & Submit application for Notification under sec - 4	144 d	Sat 5/6/17	11/8/16	3/31/17	100%	
6	Gazette Notification	49 d	########	4/1/17	5/19/17	100%	
7	Prepare & Submit application for Notification under sec - 7	32 d	########	7/30/17	8/30/17	100%	
8	Gazette Notification	182 d	########	8/31/17	2/28/18	1%	
9	Publication in Newspaper (National & Regional)	30 d	########	3/1/18	3/30/18	0%	
10	Obtain NOC from Coal Controller	30 d	Fri 3/2/18	3/31/18	4/29/18	0%	
11	Prepare & Submit application for Notification under sec - 9	180 d	########	4/30/18	10/26/18	0%	
12	Gazette Notification	30 d	Fri 9/28/18	10/27/18	11/25/18	0%	
13	Publication in Newspaper (National & Regional)	30 d	########	11/26/18	12/25/18	0%	
14	Prepare & Submit application for Notification under sec - 11	180 d	Fri 4/26/19	12/26/18	6/23/19	0%	
15	Gazette Notification u/s/11	30 d	########	6/24/19	7/23/19	0%	
16	Possession of balance tenancy land 374.53 Ha till compl	2318 d	########	11/14/15	3/19/22	30%	Ttal achievement
17	Possession of Phase-I tenancy land (13 Ha) in 2015-16	139 d	Thu 3/31/16	Sat 11/14/15	Thu 3/31/16	100%	Achievement 12.96 Ha
19	Possession of Phase-II tenancy land (78.50 Ha) in 2016-17	504 d	Fri 3/31/17	Sat 11/14/15	Fri 3/31/17	100%	Achievement 78.54 Ha
22	Possession of Phase-III tenancy land (65 Ha) in 2017-	569 d	########	Fri 9/9/16	3/31/18	94%	Achievement 61.5
23	Agreement with the Riyats for PH-III	295 d	########	Fri 9/9/16	6/30/17	100%	
24	Physical possession for Ph-III	365 d	########	4/1/17	3/31/18	90%	Achievement 61.53
25	Possession of Phase-IV tenancy land (50 Ha) in 2018	735 d	########	3/28/17	4/1/19	3%	

Results

Maintenance and Repair Contract (MARC) is concluded at the time of supply of equipment for certain high capacity equipment. MARC period is fixed at a 70% of economic life of equipment with guaranteed availability of equipment. Integrity Pact is followed by CIL such that no official will demand or accept any illicit gratification to give any of the parties an advantage at any stage of the project. All necessary and appropriate technical, legal and administrative information related to the contract will be made public. Bidder's Responsibilities are that they will not offer any illicit gratification to obtain unfair advantage; will not collude with other parties to impair transparency and fairness; will not accept any advantage in exchange for unprofessional behavior; will disclose all payments made to agents and intermediaries of all descriptions. Penalties for breach are specified. During project construction all costs are capitalised like infrastructure, machinery, installation, and even sundry revenue expenditure.

a) The model program 'qep' could be suitably modified for application not only in formulation of new projects in other mining industries, but in other project design.

b) Apart from the fast obsolescence of equipment and timely spare part availability, most crucial factor was found to be lower production than capacity of equipment, in Indian conditions, as compared to catalogue of manufacturer.

c) In the program sample run, with available mine cost data, Longwall method has shown lower A/C Return 10.75 and so model program has indicated as less suitable.

d) Table 5 shows the result of detail rescheduled MSPROJECT Chart of Jhanjra Combined Underground Project after the exercise in July'19 by the authors, in consultation with GM (Project) of the company, showing 1st page print screen.

e) The existing mines are fast depleting and new mines have to be started, but land acquisition has become critical for bureaucratic paraphernalia and actual possession of land is becoming difficult, streamlining of procedures required.

f) Scheduling of activities and monitoring for timely completion of projects, within budget can be successful.

By input of monthly quantified data in respect of all packages and activities gives one-page summary report for the month under review is very useful for fast tracking.

Discussion

Continuous Miners are mostly deployed for gate-road drivage for the LWPS. Jhanjra Project has successfully commissioned the Powered Support Longwall face which started full-fledged production from October 2016. The cumulative expenditures build up linearly [10] at a rate given by "Co/O" where "Co" is total targeted expenditure and "O" is the time for project implementation. Since

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"Co" the total targeted expenditure includes the interest on actual expenditure to be incurred (less than "Co") adjustments have to be made for this factor. Working through the details, the contribution of price increases alone or what we have called the `price factor' (PF) to cost overruns are the total cost of the project. This includes [11] the interest amortization, the annual rate of inflation, period of construction in months and rate of interest [12-20].

Present Status of Jhanjra Project

Overall picture of the project improved after critical appraisal as shown in Table 6.

Table 5: Critical Activities.

<table>
<tr><th>Head</th><th>Activities Outlined As per P.R.</th><th>Present Status</th></tr>
<tr><td>Land</td><td>Requirement of land as on 01.04.2018 in Ha.
<table>
<tr><td>Land</td><td>Required</td><td>Possession</td><td>Balance</td></tr>
<tr><td>Govt. Land</td><td>84.29</td><td>84.29</td><td>0.00</td></tr>
<tr><td>Tenancy</td><td>1322.42</td><td>854.29</td><td>468.03</td></tr>
<tr><td>Forest</td><td>168.30</td><td>90.30</td><td>78.0</td></tr>
<tr><td>Total</td><td>1575.01</td><td>1028.88</td><td>546.13</td></tr>
</table></td><td>i) Out of 468.03 Ha Tenancy land 93.60 Ha is built-up area (villages, roads etc.) for which possession is not required.
ii) Tenancy Land possessed from 01.04.2015 is 213.11 Ha till date.
Further possession of land is under process. Balance land will be
possessed in phases as per requirement.
iii) 78 Ha forest land handed over by GoWB.</td></tr>
<tr><td>Power Supply</td><td>The existing source of supply shall continue & the existing MIC incline substation will be modified by installing one additional 20 MVA 33/6.6</td><td>In the existing stage there is a 2 X 10 MVA 33/6.6 KV substation located near MIC incline. One stand by transformer is being arranged from internal resources.</td></tr>
<tr><td>Mine Development</td><td></td><td></td></tr>
<tr><td rowspan="2">Drivage of Main Inclines & Air Shaft</td><td>Drivage of Parallel Incline, 4.8 mX 3.0 m, 1 in 4.5, 316 m length; from surface to R-VII seam.</td><td>Completed, Commissioned on 08-11-15</td></tr>
<tr><td>Sinking of Shaft –F Dia 6-m, D-325 m (upto R-IV Seam)</td><td>CMPDIL submitted the Design on the basis of which Estimate (upto R-II seam in place of R-IV seam) prepared by Area and submitted to HQ. An internal meeting held on 13-2-19 in HQ for EOI. Area requested on 28-2-19 to GM(Expl), CMPDI, Ranchi for hydrological study but there was negative response from CMPDIL. EOI document prepared. EOI has been floated on 14-6-19.</td></tr>
</table>

Table 6: Rescheduling on Critical Appraisal.

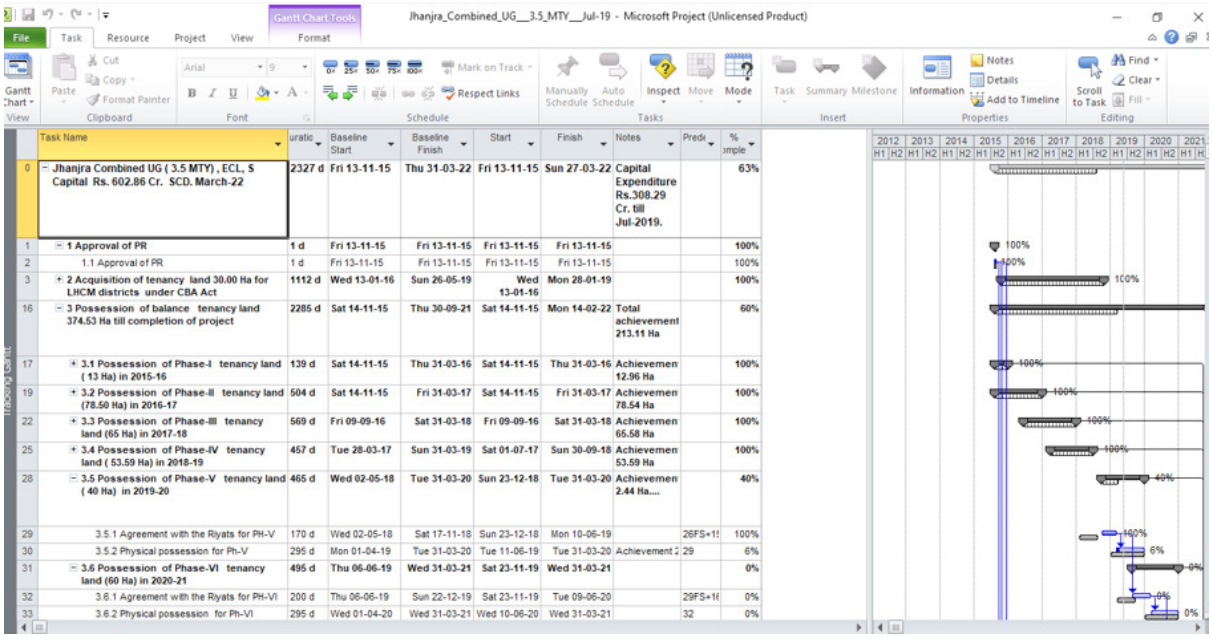

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Table 7: Project Improvement.

Head	Activities Outlined As per P.R.	Present Status
Installation of MMV	Installation of MMV in 'C' & 'E' Shafts.	Completed, Commissioned in Apr-16.
EMP	EC for 5.00 MTY under cluster no 12.	EC obtained on 03-03-2016 for capacity of 5.00 MTY.
Civil Constru on	(i) Construction of 800 Ton Bunker	Commissioning of bunker is done in Dec-2016
	(ii) Construction of 500 Ton Bunker	Commissioning of bunker is done in Dec-2016.
FC	Renewal of FC (90.30 Ha):	Stage-II for FC (90.30 Ha) obtained vide File no. 8-68/1992-FC dt. 16-8-2016.
	FC (78 Ha) new	Stage-II for FC (78 Ha) obtained on 14-3-2016 and State Govt. order on 7-04-2016.
P&M Item	(i)Construction of CHP (3.00 MTY)	(i) Draft Expansion PR for Jhanjra submitted by CMPDIL. Planning committee meeting held on 9-4-19. Final PR is expected in Jun-19.
	(ii) Construction of CHP (1.00 MTY)	A meeting held on 28-12-18, CMPDIL Planning committee meeting held on 9-4-19.

Conclusion

Strategy by Critical appraisal is the process of carefully and systematically examining research to judge its trustworthiness, its value and relevance in a particular case, here improvement of a project. The studies also showed that project management methodologies/ models should be customized/ tailored for the different projects so as to best fit the scenario and reduce cost and time. As a result of operation management exercises, one of the continuous miners at Jhanjra Project produced 5050 tonnes on 31.03.2017 which is the highest ever coal production by a continuous miner on a single day in the country. The said Longwall face produced 8,500 tonnes on 20th December 2016 and the project as a whole touched 14000 tonnes, which is the highest ever production achieved by the project. Jhanjra Project is the highest producing model underground mine of the country having state-of-art modern technologies including free steered vehicles for transportation of the workmen to the underground which has been introduced for the first time in the country. Jhanjra Project is going to be expanded to its peak capacity of 3.5 MTY. Because of the problems faced time extension of time has been accorded by the Ministry. Schedule Performance Index (SPI) = EV / PV has improved after rescheduling exercises. Method studies used here will be useful for high investment difficult projects. Excellent results could be achieved by using pits for man and material winding and Conveyors in Inclines for coal transport.

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