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Implementing PERT for Capital Repairs of a Blast Furnace: A Comprehensive Approach

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Abstract

The smooth operation of any industry or plant hinges on the seamless functioning of its various components. When a component or unit is not operational, it's termed as downtime, which is detrimental to production. Therefore, minimizing downtime is paramount from a production standpoint. To achieve this goal, modern maintenance techniques are utilized to proactively prevent any disruptions in operations.

In project planning, network analysis, particularly PERT (Program Evaluation and Review Technique), plays a significant role. PERT allows for the individual identification of each activity within a project, providing a comprehensive view of the entire system. Through the identification of activity durations, the total project completion time can be calculated. Subsequently, this time can be minimized using crashing techniques.

In the specific context of this discussion, the focus is on a blast furnace system. Network analysis, specifically applied to Category-2 repair cycles occurring every 5-8 years, has been undertaken. Activities within the repair cycle have been identified, and a time study has been conducted. Mathematical calculations have been employed to minimize the repair time during which the system is halted.

This approach aids in both time and cost savings. By minimizing the system stoppage time, production efficiency is enhanced, leading to financial savings that would otherwise be incurred due to system downtime. The collected data are factual and have undergone careful observation for the purpose of making improvements. The maintenance department is expected to derive significant benefits from this project.

Introduction

In the contemporary competitive landscape, the success of a manufacturing company hinges on the continuous and reliable operation of its plant and equipment in a cost-effective manner. To achieve this, a systematic and proactive approach to maintenance is essential.

This involves continuous planning for the well-being of all critical equipment, with preventive actions taken in a timely fashion to avert equipment failures. The implementation of diverse programs aimed at reducing downtime due to maintenance can significantly enhance the efficiency of the maintenance function.

When a machine within the production system experiences a failure, it leads to a full or partial system failure, causing delays during remedial actions. To manage delay costs effectively, it is imperative to keep system downtime to a minimum and enhance system availability. In this context, key parameters such as maintenance, manpower, tools/spares, and diagnostic equipment play a crucial role, gaining heightened importance during the implementation of maintenance functions.

As modern production systems evolve towards increased specialization, automation, and high capital intensity, the overhead and delay costs associated with system failures become substantial and must be minimized. This underscores the necessity of a well-executed and timely maintenance strategy to optimize production efficiency and mitigate costs.

Methodology

Programme Evaluation Review Technique (PERT)

PERT, first employed in 1957 to plan and manage the Polaris missiles Program, was developed by Booz, Allen and Hamilton in partnership with the U.S. Naval department, aimed to complete the project two years ahead of schedule. It constitutes a fundamental network technique encompassing project planning, monitoring, and control. PERT is applicable for managing complex sets of tasks, functions, and relationships, making it a crucial tool in project management. Widely employed for the initial project review, PERT serves as a valuable device for planning time and resources. As a significant contribution to managerial science, PERT identifies potential trouble areas that could jeopardize program objectives, enabling timely intervention to prevent disruptions. PERT plays a pivotal role in decision-making processes[9].

PERT Planning Techniques.

The PERT planning technique involves a systematic series of steps:

- The project is systematically decomposed into various activities.
- Activities are arranged in a coherent sequence. • A network diagram is created, assigning numbers to both events and activities.
- Using three time estimates, the anticipated duration for each activity is determined.

- The standard deviation and variance for each activity are computed.
- Earliest start times and latest finish times are established.
- The expected time, earliest start time, and latest finish times are indicated on the network diagram.
- Slack, which denotes the flexibility in activity timings, is evaluated.
- Critical path(s) are identified and emphasized on the network diagram.
- The length of the critical path or the total project duration is determined.
- Lastly, the likelihood that the project will meet the deadline is calculated, offering insights into the project's timeliness.

Estimation of Activity time.

The PERT (Program Evaluation and Review Technique) approach calculates the expected time for each activity by considering three time estimates:

(a) Optimistic time: This denotes the minimum amount of time required for an activity to be completed under ideal conditions, assuming everything progresses exceptionally well.

(b) Most likely time: This refers to the timeframe during which the activity is expected to be completed under standard or typical conditions.

(c) Pessimistic time: This indicates the longest time it would take for an activity to be completed, assuming that most things go wrong or there are significant difficulties.

To compute the expected time for each activity using PERT, the formula generally involves taking a weighted average of these three-time estimates[5].

CPM theory

One prevalent project estimation approach is the Critical Path Method (CPM). Project managers utilizing CPM typically disregard probabilities and rely solely on nominal case estimates.

CPM Technique

CPM employs the following steps for accomplishing a project planning;

- Break down the project into various activities systematically.
- Assign labels to all activities.

- Arrange the activities in a logical sequence.
- Construct the arrow diagram.
- Number all nodes (events) and activities.
- Determine the duration for each activity.
- Place activity durations on the arrow diagram. • Compute early and late start and finish times.
- Tabulate various times and denote EST and LFT on the arrow diagram.
- Calculate total float for each activity.
- Identify critical activities and indicate the critical path on the arrow diagram.
- Determine the total project duration.
- If reducing the total project duration is desired, expedite the critical activities within the network.
- Optimize costs.
- Update the network accordingly. • Optimize the allocation of network resources.

One frequently employed project estimation technique is the Critical Path Method (CPM). Project managers utilizing CPM often prioritize nominal case estimates over probabilities[14].

Dependencies

Both PERT and CPM visually represent projects through diagrams showcasing tasks and their interconnections. The simplified diagrams provided above depict three tasks with sequential dependencies. The arrow from Task 1 to Task 2 indicates that Task 2's start depends on Task 1's completion; Task 2 cannot commence until Task 1 finishes. As projects scale up, these charts can become considerably intricate [7].

The provided chart exhibits a project with numerous tasks and dependencies. Initially, three tasks (t1, t9, and t5) commence concurrently, while others initiate upon the completion of these tasks. It's noteworthy that t6 and t7 can only commence after t5 concludes, and t3's commencement hinges on the completion of both t2 and t6.

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The longest route through this network, termed the Critical Path, lends its name to CPM. The critical path is highlighted in bold. This path offers insights into the project's timeline, indicating that the end event is projected to occur 26 days from the start event.

In the context of PERT, the date of the end event would be a stochastic variable based on the mean (μ) and standard deviation (s) of each task on the critical path. Moreover, it would enable the calculation of probabilities associated with other paths potentially becoming critical[17].

Repair description schedule

Blowing Out Procedure:

Following the cessation of furnace operations, the expulsion of internal molten metal deposits is initiated, a process commonly referred to as Salamander Tapping. Subsequently, the furnace undergoes gradual cooling. Salamander tapping entails the removal of molten metal slag and residual material up to the hearth level[10].

Upon completion of the salamander tapping process, the furnace becomes primed for capital repair. Given the furnace's hollow structure, characterized by refractory lining lining the walls throughout, accessibility to all heights becomes a logistical challenge. In response to this challenge, three hanging platforms are set up using electric winches and secured to fixed structures at the summit. Positioned at different heights, these platforms enable concurrent repair tasks and the application of refractory lining during maintenance procedures.

For extensive repairs such as this, multiple detartments are involved. It's crucial to kick off discussions and schedule repair planning meetings no later than six months prior to secure agency bookings and commence spare parts procurement and fabrication internally. Prior to any category-2 capital repair, a minimum of four to five preparatory meetings are convened. A dedicated group from the shop floor is tasked with formulating repair plans[12].

Commonly-invited agencies for assistance in this endeavor include:

- Instrumentation Department
- Hydraulics and Lubrication Department
- Central Technical Services
- Safety Engineering Department
- Capital Repair Modification Group
- Energy Management Department
- Project Department
- Refractory Engineering Department

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- o Building and Structural Inspection
- o Water Supply Department
- o HSCL Contract Civil Jobs
- o General Maintenance Group
- o Transport and Diesel (Traffic) Department
- o Central Heavy Maintenance
- o Design and Drawing Department
- o Equipment Inspection Department
- o Materials Recovery Department
- o Bearing Engineering Department
- o Pipeline Erection and Maintenance
- o Central Machine Shops
- o HSCL Contract Mechanical Jobs
- o Bhilai Engineering Design Bureau
- o Civil Engineering Department

Additionally, other departments may be involved as deemed necessary. Daily morning and evening meetings are conducted throughout the repair period to address any issues and monitor progress[10].

Data Collection, Formulation & Calculations

Data from the blast furnace plant indicate the following details regarding the repair process with number of days for completion:

Total duration of repair: 90 days

Activities involved in the repair cycle include:

- Preliminary tasks involve disassembling charging appliances and lowering hanging platforms (HPs), along with removing shaft refractory lining down to the Bosh level. (10)
- Dismantling the Bosh & Mantle Ring (MR) coolers (12)
- Dismantling the lining of TZ refractory (1)
- Dismantling the TA & TZ coolers (2)
- Installation of Bosh & MR coolers and securing of hanging platforms (4)
- Removing the refractory lining all the way to the Iron notch (4)

- Disassembling the refractory lining all the way up to the Upper Hearth Bottom (UHB) (18)
- Replacing the UHB coolers (3)
- First, the refractory building process begins with the initial 9 layers of the hearth bottom. (14)
- Installation of Hearth & TZ coolers (4)
- Dismantling the protection platform. (1)
- Reconstruction of hearth refractories up to TZ (7)
- Relining the TZ area (2)
- Relining and cleaning of Bosh area (2)
- Lowering, cutting, and removing all suspended platforms (2)
- Testing and rectifying pressure (2)
- Charging the shell in the bosh area, mantle ring area, and shaft zone; Installing shaft coolers; Substituting protective segments; Fixing dome lining plates and uptake pipes. (9)
- Repairs in the Hoist House encompassing skip winches, SLI (stock level indicator) winches, and hydraulic oil pumps; Repairs in the Cast House involve tasks like replacing blow pipe assemblies, repairing the cast house crane, and attending to the rocking runner and cast house runner. (4)
- Repairing tasks within the stove house encompassing hot blast and cold blast valve repairs, stove shell maintenance, and rebuilding chimney valves and pipes. (4)
- Replacing skip buckets, repairing skip tracks, and undertaking tasks related to cooling pipes, air conditioning, and ventilation systems. (4)
- Repair of dust catchers, bunkers, and gates; Blower maintenance (4)
- Repairing bleeders at the furnace top and conducting maintenance on the slag granulation plant. (4)
- Replacing the drilling machine and mud gun, conducting a thorough overhaul of the cast house crane, and servicing the skip winch pulley on both the top and middle platforms. (8)
- Performing civil work for repairing blast furnace foundation columns; Conducting root repairs at the cast house, hoist house, and stove platform. (16)

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- Rehabilitation of stock house, encompassing bunkers, ore & coke screens, and hopper restoration (9)
- Below ground, the skip track repairs, gates servicing, and screens reinforcement. The conveyor system for stock to receive a comprehensive repair job, ensuring its smooth operation. (8)

All activities are presented here along with their respective time durations. Contractual laborers are enlisted for the execution of these activities. The cost per laborer per shift amounts to Rs. 500/-. This cost encompasses labor wages, tools expenses, power usage, and miscellaneous expenditures.

Formulation & Computation: After closely scrutinizing the activities involved in the repair cycle, a PERT network has been constructed, illustrated on the subsequent page. Utilizing this network as a framework, PERT chart calculations have been performed. These calculations have facilitated the determination of slack times, subsequently aiding in the identification of critical activities. Upon pinpointing critical activities, measures to expedite these processes, known as crashing, have been implemented to mitigate the overall path duration. Following the crashing process, a revised network has been formed[16].

Table No.01

S. No.	Activity	Earliest starting time	Latest completion time	Slack
01.	**0-1**	**0**	**0**	**0**
02.	**1-2**	**10**	**10**	**0**
03.	**1-2’**	**10**	**10**	**0**
04	**2-3**	**22**	**22**	**0**
05	2’-3’	10	66	56
06.	**3-4**	**25**	**25**	**0**
07.	3’-4’	14	70	56
08.	**4-5**	**26**	**26**	**0**
09.	4’-5’	18	74	56
10.	**5-6**	**28**	**28**	**0**
11.	**6-7**	**32**	**32**	**0**
12.	**6-7’**	**32**	**32**	**0**
13.	**7-8**	**36**	**36**	**0**
14.	7’-8’	40	57	17
15.	**8-9**	**54**	**54**	**0**

16.	8'-9'	49	66	17
17.	**9-10**	**57**	**57**	**0**
18.	5'-9'	22	78	56
19.	**10-11**	**71**	**71**	**0**
20.	9'-10'	65	82	17
21.	**11-12**	**75**	**75**	**0**
22. -	10'-17	73	90	17
23.	**13-14**	**82**	**82**	**0**
24.	**14-15**	**84**	**84**	**0**
25.	**15-16**	**86**	**86**	**0**
26.	**16-17**	**88**	**88**	**0**

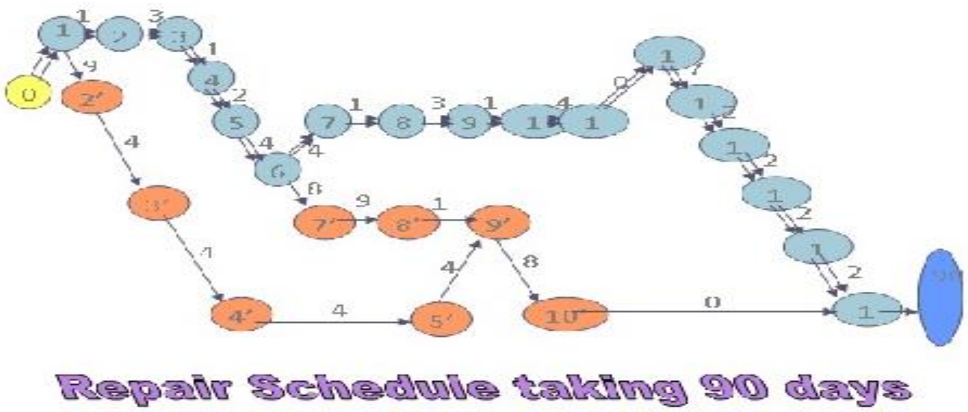

Figure.1. Repair schedule taking 90 days

3. Critical activities before improvement

S.No.	Job description	No. of days
01.	Preparatory jobs, dismantling of charging appliances, lowering of hanging platforms (HPs)	10
02.	Dismantling of Shaft refractory lining up to Bosh	12
03.	Dismantling of Bosh & Mantle ring (MR) coolers	3
04.	Dismantling of TZ refractory lining	1
05.	Dismantling of TA & TZ coolers	2
06.	Erection of Bosh & MR coolers and sealing of HP	4
07.	Dismantling of refractory lining up to Iron notch	4
08.	Dismantling of refractory lining up to Upper Hearth Bottom (UHB)	18
09.	Changing of UHB coolers	3
10.	Refractory building of hearth bottom first 9 layers	14
11.	Erection of Hearth & TZ coolers	4

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12.	Removal of protection platform	1
13.	Refractory rebuilding of hearth up to TZ	7
14.	Relining of TZ area	2
15.	Relining of Bosh area & cleaning	2
16.	Lowering, cutting & removal of all hanging plat forms	2
17.	Pressure testing & rectification.	2
	Total	**90 days**

Critical activities after improvement (Crashing)

S.No.	**Job description**	**No. Of days**
01.	Preparatory jobs, dismantling of charging appliances, lowering of hanging platforms (HPs)	7
02.	Dismantling of Shaft refractory lining up to Bosh	8
03.	Dismantling of Bosh & Mantle ring (MR) coolers	3
04.	Dismantling of TZ refractory lining	1
05.	Dismantling of TA & TZ coolers	1
06.	Erection of Bosh & MR coolers and sealing of HP	3
07.	Dismantling of refractory lining up to Iron notch	3
08.	Dismantling of refractory lining up to Upper Hearth Bottom (UHB)	14
09.	Changing of UHB coolers	3
10.	Refractory building of hearth bottom first 9 layers	9
11.	Erection of Hearth & TZ coolers	4
12.	Removal of protection platform	1
13.	Refractory rebuilding of hearth up to TZ	5
14.	Relining of TZ area	2
15.	Relining of Bosh area & cleaning	2
16.	Lowering, cutting & removal of all hanging plat forms	2
17.	Pressure testing & rectification.	2
	Total	**70 days**

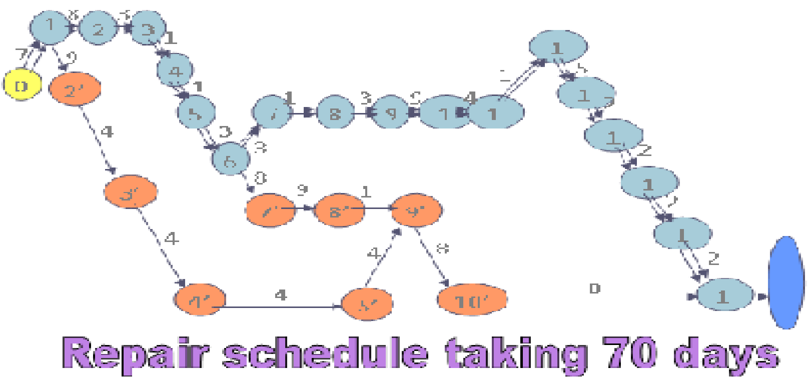

Figure.2. Repair schedule taking 70 days

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After implementing the necessary adjustments, this network diagram illustrates a notable reduction in project duration, from 90 to 70 days. Prior to the improvements, availability stood at 0.95300, while post-improvement, it increased to 0.9630. Consequently, downtime saw a reduction of 20 days[18].

Conclusion:

The enhancements in availability showcased here signify a substantial improvement, promising greater economic efficiency within the system. By mitigating downtime by a span of 20 days through repairs, there exists a tangible opportunity to curtail costs. Let's explore potential strategies to achieve this. Considering a person's cost per shift amounts to approximately Rs. 500, encompassing labor expenses, tool and equipment costs, power consumption, and sundry expenditures, it's pertinent to juxtapose the expenses in two scenarios.

Cost comparison (comparison between normal & crash costs of repair)

S. no.	Activity	Normal duration	Crash duration	Persons required (normal)	Personas required (crash)	Normal cost (Rs.)	Crash cost (Rs.)
01.	Preparatory jobs, dismantling of charging appliances, lowering of hanging platforms (HPs)	10	07	14	20	210000	210000
02.	Dismantling of Shaft refractory lining up to Bosh	12	08	15	23	270000	276000
03.	Dismantling of Bosh & Mantle ring (MR) coolers	03	03	14	14	63000	63000
04.	Dismantling of TZ refractory lining	01	01	15	15	22500	22500
05.	Dismantling of TA & TZ coolers	02	01	14	28	42000	42000
06.	Erection of Bosh & MR coolers and sealing of HP	04	03	14	20	84000	45000
07.	Dismantling of refractory lining up to Iron notch	04	03	15	20	90000	90000

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08.	Dismantling of refractory lining up to Upper Hearth Bottom (UHB	18	14	15	20	405000	420000
09.	Changing of UHB coolers	03	03	14	14	63000	63000
10.	Refractory building of hearth bottom first 9 layers	14	09	14	22	294000	297000
11.	Erection of Hearth & TZ coolers	04	04	14	14	84000	84000
12.	Removal of protection platform	00	01	14	14	-------	21000
13.	Refractory rebuilding of hearth up to TZ	07	05				
14.	Relining of TZ area	02	02	20	25	180000	337500
15.	Relining of Bosh area & cleaning	02	02				
16.	Lowering, cutting & removal of all hanging plat forms	02	02	14	14	42000	42000
17.	Pressure testing & rectification.	02	02	28	28	84000	84000
	Total	90	70	219	281	1933500	2051500

The total normal cost includes both direct and indirect costs.

The direct cost, which is the cost of repair, amounts to Rs. 1,933,500.

On the other hand, the indirect cost, which accounts for the loss due to stoppage of the furnace, is Rs. 537,600,000.

Therefore, the total normal cost sums up to Rs. 539,533,500.

Now, let's delve into the total crash cost.

This includes the cost of repair, which is Rs. 2,051,500,

and the additional loss incurred due to a 20-day delay in repair time.

By subtracting the total crash cost from the total normal cost, we find a difference of Rs. 537,482,000.

This signifies a substantial saving of approximately Rs. 53 crores resulting from this modification in the cycle. Such significant savings underscore the logistical importance of these findings.

Moreover, this cost-saving can be allocated to motivate employees and workers through extra incentives or rewards. Fostering good human relations within the organization is paramount for its success. Therefore, utilizing these savings to enhance employee satisfaction is essential.

The benefits of early completion extend beyond cost savings. They include improved system availability, reduced losses due to delays, lowered production costs, and heightened employee satisfaction. These advantages collectively contribute to the overall efficiency and success of the organization.

Future Scope

In forthcoming research, we plan to incorporate parameters such as inventory control and ABC analysis, drawing inspiration from the insights provided in this paper. This work stands poised to offer valuable guidance for future studies and adjustments. Just as in this instance, other domains could benefit from similar adaptations. Indeed, this paper holds promise as a foundational tool for addressing analogous challenges across various systems.

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