ACTIVITY CRASHING IN SHUTDOWN MAINTENANCE THROUGH QUALITATIVE ASSESSMENT: A CASE STUDY

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Abstract:
This paper presents a methodology to solve the complex problem of activity crashing in project management. The methodology is based on qualitative assessment of various parameters such as technical difficulty, requirement of additional resources, adverse effect of crashing on quality and safety, extent of uncertainty, etc. for identification of critical activities for crashing. The methodology is illustrated through a case study of shutdown maintenance work, done in a medium sized thermal power plant situated in the state of Odisha in India. Shutdown maintenance work in any process plant consists of numerous inter-related activities and is managed as a project. Since the plant remains idle during the shutdown period, it is very important to complete the shutdown maintenance work in minimum time. Activity crashing sometimes becomes necessary to reduce the duration of a project. But quantitative and analytical methods are often difficult to apply due to high complexity involved in activity crashing in the real project scenario. The case study shows that systematic application of qualitative assessment through participation of people (i.e. team, committee, etc) can be a preferable and effective technique to solve complex problems in any project management work.

Key Words: Activity Crashing, Shutdown Maintenance, Qualitative Assessment, Project Scheduling

1. INTRODUCTION

Shutdown maintenance work is very important for any process plant. During shutdown maintenance, the operations of different units of plant are closed for significant duration for checking, overhauling and replacement of worn-out components. Since the plant remains idle during the shutdown period, it is very important to complete the shutdown maintenance work in minimum time. The maintenance work consists of numerous inter-related activities and involves significant amount of resource and cost. The maintenance period has a well defined start date and end date. So shutdown maintenance work can be managed as a project. Activity crashing is done to reduce the duration of a project. But due to high complexity, quantitative and analytical methods are sometimes difficult to apply for activity crashing in the real project scenario. This paper presents a methodology based on qualitative assessment and group decision-making for activity crashing to reduce the duration of a project. The methodology is illustrated through a case study done in a medium sized thermal power plant situated in Orissa, India.

2. SHUTDOWN MAINTENANCE OF THERMAL POWER PLANT

Periodic overhauling of thermal power plant is necessary for good performance. Since it is impossible to do thorough overhauling and repair work while the unit is in operation, the unit is shutdown in a planned manner for annual maintenance. This is referred to as "shutdown maintenance". During shutdown maintenance, the operation of different units of plant is closed for significant duration for checking, overhauling and replacement of worn-out components.

The shutdown maintenance is a classic example of a project management scenario. It may be noted that the Critical Path Method (CPM) was first developed for a maintenance shutdown of DuPont Chemical Plant in 1957. The shutdown maintenance is a complex and constrained process that requires close coordination of workers and materials. There is a high degree of uncertainty because of the nature of maintenance and repair work. The shutdown maintenance of thermal power plant consists of numerous inter-related activities. It involves high cost, time and resources and has well defined start and end date. So shutdown maintenance of thermal power plant is managed as a project.

Case study pertains to medium sized thermal power plant situated in Orissa State in India. The plant had 8 power generating units of 120MW each. Each of the plant's eight units consists of a furnace, boiler, turbine and generator. Shutdown maintenance of a thermal power plant involves overhauling of all its subsystems. Overhauling of each subsystem consists of number of related activities. Planned duration, work content and number of activities performed in overhauling of major subsystems of power plant is shown in appendix-A. The plant is shut down for overhauling in planned and phased manner. All the units are not shut down at the same time. Rather the units are shut down in turn, one at a time so that while one unit is under shutdown other units are in operation.

Boiler is a major subsystem of thermal power plant. Its normal overhauling consisted of 52 activities and the planned duration was 36 days. It was observed that the actual time taken to complete the overhauling work often exceeded the planned duration. The overhauling work of boiler was identified as one of areas that had scope of improvement. A target was set to reduce the planned duration of boiler overhauling work from 36 days to 33 days; and also to reduce the gap between actual and planned duration. This paper presents this case study of activity crashing in overhauling work of Boiler subsystem.

3. ACTIVITY CRASHING IN PROJECT MANAGEMENT

The duration of a project can be reduced by crashing the duration of critical activities. Activity crashing is done by using extra cost and resources. Since minimizing the time and the cost are both important objectives of project management, the activity crashing or project expediting process can be transferred to the typical time-cost trade-off analysis [1].

Traditionally, the time-cost problem is addressed by CPM-based analytical approaches [2, 3]. Analytical methods involve lot of computation work and are difficult to apply even to a medium sized project consisting of hundreds of activities [4]. So for simplification, we assume existence of unlimited resources and a continuous linear time-cost function. But in most practical situations, there is constraint on resources and non-linear relationship between time and cost. Further, due to discrete nature of most resources, the time-cost function is not continuous and the activities can only be crashed stepwise. De et al have shown activity-crashing problem to be NP-hard for discrete time-cost relationship [5]. So the efforts have turned to finding the approximation and heuristics methods to solve these problems [6, 7, 8].

Qualitative assessment and group decision-making can be another approach to solve complex problems such as the problem of activity crashing to reduce the duration of projects. Makui et al., have shown that group decision making methodology can be effectively used in project risk identification and analysis in a fuzzy environment [9]. They have concluded that

in many of such decision-making settings the theory of group decision-making can play crucial role.

4. PROBLEMS OF ACTIVITY CRASHING

Activity crashing to reduce the total duration for overhauling of any process plant, such as thermal power plant, possesses high complexities due to following reasons.

- **Uncertainty:** The total duration of project, critical path and critical activities are determined based on estimated time. But the time needed to overhaul any part depends on actual condition of the part. So there is variation in work content of different activities. Further there is uncertainty due to sudden breakdown of some machines or occurrence of some unforeseen events, for which the progress of some activities may be delayed.
- **Resource constraint:** Crashing of activities faces problem due to resource constraint. In addition to resource constraint there is also the need for resource levelling.
- **Non-availability of Spares:** Many spare parts are needed during overhauling. But their exact requirement becomes known only at the time of overhauling. The spare parts are stocked based on anticipation. But in order to reduce inventory cost, there is constraint on amount of spares that can be stored. So non-availability of some spares sometimes affects the progress of overhauling work.
- **Activity Relationship:** In case of overhauling of any process plant, the relationship among activities is sometimes quite fuzzy. Sometimes due to unavailability of spares or other problems, it becomes necessary to interrupt an activity and start another activity by deviating from the predetermined sequence. Most analytical approaches for solving activity crashing problem assume finish-to-start relationship between activities. But in practice, finish-to-start relationship between activities is not rigidly followed in all cases.
- **Estimation of cost of crashing:** The cost incurred to crash activity duration by one time unit, is an important parameter for selection of an activity for crashing. But practically, it is very difficult to estimate the additional cost and resource required for activity crashing. Also the past data for the same is usually not available.
- **Non-availability of accurate time standard:** In comparison to production work, the maintenance work is much uncertain and non-routine in nature. So it is difficult to determine and apply individual time standard for each task.
- **Quality Requirements:** It is difficult to exactly specify the quality and safety requirements of overhauling work. It is also difficult to determine the effect of expediting an activity on overall quality and safety of the plant.
- **Organizational Behaviour Aspects:** Most of the tasks of shutdown maintenance are carried out collectively by number of persons as teams. The members of the team have specified roles for each individual task. So if size or structure of a team is changed for activity crashing, it may become necessary to redefine the role of individual members with respect to the activity being crashed. So activity crashing also involves organization behavioural aspects.

Due to high complexities, it is very difficult to mathematically solve the problem of activity crashing in overhauling of thermal power plant.

5. APPROACH ADOPTED FOR ACTIVITY CRASHING

This case study pertains to a thermal power plant which, is known for its commitment to quality. The plant is certified by ISO 9001, ISO 14001, OHSAS 18001 and the government for its quality endeavour. It has a full fledge TQM department and numerous actively

functioning Quality Circles (QC). The reduction in overall duration of overhauling period of thermal power plant was selected as one of the important areas for quality and productivity improvement program. Activity crashing to reduce the total duration for overhauling of Boiler subsystem was done jointly by the quality team and the quality circles of maintenance department. The approaches followed for activity crashing are as under.

- Total participation of people: i.e. participation by quality team and the QCs.
- Group decision making: The decisions required for reducing the duration of overhaul period was not imposed but was taken by involving the concerned people on the basis of some consensus.
- Qualitative assessment of different parameters of activities: Since quantitative data were not available for some parameters, qualitative assessment was used as a means for analysis.
- Group Incentive and Recognition: This was used as the motivation for activity crashing.

The quality team planned and implemented activity crashing based on a model that consisted of following steps.

i) List all activities performed in overhauling project.
ii) Determine relationship between activities.
iii) Determine Earliest Start Time (EST), Earliest Finish Time (EFT), Latest Start Time (LST) and Latest Finish Time (LFT) of all activities. Determine float.
iv) Identify all critical paths and the critical activities. Do qualitative evaluation of various parameters involved in crashing an activity such as technical difficulty, requirement of additional resources, adverse effect of crashing on quality and safety, extent of uncertainty, etc.
v) Prepare the tentative list of activities to be crashed.
vi) Analyze each activity from the tentative list and estimate what extra resource and/or overtime will be needed for crashing.
vii) Identify the non-critical activities. Examine if any resource can be diverted from these non-critical activities by allowing some more time for their completion.
viii) Make the final selection of activity to be crashed.
ix) Repeat the steps from step-III to step-VIII for next iteration.

6. IMPLEMENTATION AND RESULT

The approach and model described at above was implemented for crashing the duration of overhauling period of boiler. The list of activities, their relationship, duration and resource requirement for overhauling of Boiler Subsystem is shown in appendix-B. This problem of activity crashing possessed all the complexities as listed earlier in section 4 of this article.
Analysis was done to identify the critical and the non-critical activities based on three parameters; (1) availability of float, (2) amount of uncertainty and risk, and (3) number of immediately succeeding activities. The activities are rated subjectively according to grading system as given in Table I.

Table I: Rating scale for identification of critical activities.

Parameter 1: Availability of Float (Assigned weight = 0.5)		Parameter 2: Uncertainty and risk (Assigned weight = 0.3)		Parameter 3: Number of succeeding activities (Assigned weight = 0.2)	
Scale	Rating	Scale	Rating	Scale	Rating
Float up to 1 day	A	Highly uncertain	A	3 or more	A
Float up to 4 days	B	Moderately uncertain	B	2 to 3	B
Float greater than 4 days	C	Negligibly uncertain	C	less than 2	C
Points Score: A = 10; B = 6; C = 2					

The above grading system was jointly decided by members of quality team and quality circle of maintenance department. The total score of each activity was calculated as under.

Total score = $p_1 w_1 + p_2 w_2 + p_3 w_3$

Where p_1, p_2 and p_3 are points score for parameters 1, 2 and 3 respectively; and w_1, w_2 and w_3 are corresponding weights assigned to three parameters. Based on collective opinion of group members, the activities whose total score was 7 or more were identified as critical. Similarly activities whose total score was 3 or less were identified as non-critical activities. The list of critical and non-critical activities is shown in Table II.

Table II: List of critical and non-critical activities.

Critical Activities	1, 2, 8, 9, 12, 19, 22, 23, 36, 39, 42, 47, 48, 50, 51, 52
Non-Critical Activities	3, 4, 5, 11, 14, 16, 18, 20, 21, 27, 34, 45

Table III: Categorization of critical activities.

Activity that are:	**Easy to crash**	**Moderately easy to crash**	**Difficult to crash**
Activity Number →	23, 9, 48, 52	2, 8, 12, 19	1, 22, 36, 39, 42, 47, 50, 51

Table IV: Revised duration of activities.

Sl. No	Activity No.	Name of the Activity	Earlier duration in days	Revised duration in days	Remark
1	4	Duck house cleaning	10	14	1 semi-skilled and 1 unskilled worker removed from the activity
2	9	Servicing of hydro test line valves	16	14	Additional 1 semi-skilled and 1 unskilled worker assigned to activity
3	12	Scarf 1st pass	5	4	Additional 1 semi-skilled and 1 unskilled worker assigned to activity
4	16	Rotor alignment/ Drive system servicing/ Sector plate alignment/ Oil seal setting/ Repair of Basket support, Air heater support / etc.	20	24	2 semi-skilled workers removed from the activity
5	18	Pent house cleaning	5	7	1 semi-skilled and 1 unskilled worker removed from the activity
6	23	Pressure parts repair	8	7	Additional 2 semi-skilled workers assigned to the activity
7	46	Field charging & Rectification	2	3	Additional 1 semi-skilled worker assigned to activity and 2 unskilled workers removed
8	48	Area floor cleaning	4	3	Additional 2 unskilled worker assigned to activity and 1 semi-skilled worker removed
9	52	Trial and Final Steam dumping Floating	2	1	Additional 1 skilled, 1 semi-skilled and 3 unskilled workers assigned to the activity

In the same way, the critical activities were analyzed to identify the activities that are easy to crash. This was done by qualitative assessment on four parameters, namely (1) scope for crashing, (2) requirement of additional resources for crashing, (3) adverse affect of crashing on quality and (4) adverse affect of crashing on safety. Based on group opinion, the parameters were assigned weight 0.4, 0.2, 0.2 and 0.2 respectively. The critical activities were categorized in to three groups based on ease with which these can be crashed. Categorization of critical activities is shown in Table III. To minimize the bias in subjective assessment, the activities were rated independently by three to four experienced/ knowledgeable persons and average score was considered for decision-making.

In the first iteration, the activity number 1, 2, 8, 12, 23 and 48 were selected as the most critical activities. This tentative list of activities was analyzed. Based on brain storming in Quality Team and Quality Circle, the activity number 23 was selected as the first activity to be crashed. On crashing this activity, the planned duration of project was reduced from 36 to 35 days. In the next subsequent iterations, more activities were added to the tentative list

and the above process was repeated. After qualitative analysis and discussion in the maintenance team meeting and in the Quality Circle meetings, more activities were selected for crashing. In addition to critical activities, the non-critical activities were also examined and resources were diverted from some of these activities by allowing some more time for their completion. The list of activities that were revised is shown in Table IV. Thus by revising the duration of some activities, the planned duration of boiler overhauling project was reduced from 36 days to 33 days.

7. CONCLUSION

Overhauling of a thermal power plant is done by shutting down its operation. So it is very important to complete the overhauling work in minimum time. This is done by selectively crashing the duration of some activities of overhauling work. The duration of an activity is crashed by incurring extra cost and resources.

The problem of selecting activities for crashing possesses high complexities. In an organization there are staff changes, system changes, and changes in the scope of the problem. As the equipment gets older, the requirement for maintenance is increased. Due to repetitive nature, the people get skilled in the work. They also use shortcuts to do the work in less time. So there is need to periodically review and make necessary changes in the project management system.

A particular diagram may not work for the same job every year. Sequence and precedence, are often style decisions, not technological imperatives. Another manager or team may not have the same definitions and sequence ideas. So, if a particular network diagram is rigidly imposed on people, it results in frustration, misunderstanding, and error.

In project management scenario, there is much uncertainty and also significant error in project estimate. So the exact solution obtained by analytical and quantitative techniques is also prone to error. Due to high complexities, it is also difficult to apply analytical and quantitative techniques to activity crashing problem. The qualitative assessment can be useful technique in these situations. This study illustrates how the complex problem of activity crashing can be solved by qualitative assessment through participation and involvement of people, and teamwork.

Reduction by three days meant that each unit can operate for three more days in a year. This meant additional production of 69120 MWH of electricity. Here it may be noted that earlier though the planned duration was 36 days, it was invariably taking more time than the planned duration. Sometimes the duration was as much as 42 days. But with group participation the planned duration was not only reduced to 33 days but was also achieved.

Thus, it can be concluded that systematic application of qualitative assessment through participation of people (i.e. team, committee, etc) can be a preferable and effective technique to solve complex problems in any project management work.

APPENDICES

Appendix A: Overhauling of Major Subsystems of Power Plant.

SL No.	Major Subsystems of Power Plant	Number of Activities	Duration in Days	Work Content in Man-Days
1	Boiler and Auxiliary	52	36	1620
2	Ash Handling System & Civil work	24	33	495
3	Air- Pre-Heater	2	33	594
4	Mills	20	32	960
5	Feeders	2	8	48
6	Civil & Mechanical work	14	29	435
7	Turbine	36	33	660
8	LT/HT Motors	44	29	725
9	Generator & Auxiliary	21	32	320
10	Actuator	6	34	102
11	Switch Gear	15	35	245
12	Automatic Voltage Regulator relay and Battery	8	27	162
13	Transformer	4	29	174
14	Pressure Reducing Damper System (PRDS)	3	35	140
15	Secondary Air Damper System (SADC)	3	29	116
16	Furnace Safeguard and Supervision System (FSSS)	8	30	120
17	Analog Control System (Boiler)	15	35	140
18	Automatic Turbine Run-up System	23	35	140
19	Analog Control System (Turbine)	19	29	145
20	Cooling Tower	13	25	150

Appendix B: List of Activities performed in Overhauling of Boiler.

Sl. No	Name of Activity	Predecessor Activity	Duration of the job in Days	Resources High skille	Semi skille	Un- skille
1	Cooling	---	2	1	2	3
2	Fuel firing equipment servicing	---	27	2	7	4
3	Primary Air fan servicing (1st)	---	18	1	3	5
4	Duck house cleaning	---	10	1	3	6
5	Force Draft fan servicing (1st)	---	17	1	4	8
6	Ingot Draft fan servicing (1st)	---	18	1	2	7
7	Servicing of ESP	---	24	2	9	6
8	Scaff 2nd pass	1	2	1	3	5
9	Servicing of hydro test line valves	---	16	1	4	9
10	Servicing of air & fuel gas damper	---	19	1	5	9
11	Secondary Air Damper System servicing	---	21	2	6	7
12	Scarf 1st pass	8	5	1	2	5
13	2nd pass cleaning	8	4	1	3	6
14	Repair of ducts	---	22	2	4	7
15	Soot boiler servicing over hauling & sleeve replacement	---	20	2	5	8
16	Rotor alignment/ Drive system servicing/ Sector plate alignment/ Oil seal setting/ Repair of Basket support, Air heater support / etc.	---	20	2	7	9
17	2nd pass T-T survey & 1st pass tube thickness survey (By condition monitoring T-T)	13	14	1	3	6
18	Pent house cleaning	---	5	1	2	5
19	1st pass cleaning	12	6	1	3	7
20	Repair of duck house	4	11	1	2	5
21	Pent house repair	18	12	1	2	6
22	Drying & prepare for T-T survey	10	2	1	2	6
23	Pressure parts repair	22	8	1	3	7
24	Primary Air fan servicing (2nd)	3	2	1	4	9
25	Water wall tube replacement	22	7	1	3	7
26	Servicing of non-hydro test line valve	9	9	1	4	8
27	Force Draft fan servicing (2nd)	5	2	1	2	4
28	Elect & C & I work	24	4	1	2	5
29	Ingot Draft fan servicing (2nd)	6	2	1	3	6
30	Elect & C & I commissioning	24	3	1	4	7
31	Jobs elect & C&I work	29	5	1	5	8
32	Commissioning work	10	8	1	3	5
33	Commissioning jobs	31	3	1	2	6
34	Protection check	30	3	1	6	9
35	C & I jobs	11	5	1	4	7
36	HT & React	23, 25	1	1	3	7
37	Soot boiler commissioning	14	5	1	2	5
38	Repair & rectification	7	2	1	3	7
39	Final HT	36	1	1	1	2
40	Box-up f/f system	2	2	1	2	3
41	Commissioning jobs	31	3	1	3	5
42	Scaff removal	39	3	1	3	5
43	C & I commissioning jobs	2	3	1	3	5
44	Commissioning of valve servicing	26	3	1	2	4
45	Commissioning	16	2	1	4	6
46	Field charging & Rectification	38	2	1	5	8
47	Box up	32, 42	1	1	2	5
48	Area floor cleaning	42	4	1	3	6
49	Testing	37	3	1	2	5
50	Boiler water washing	47	1	1	2	6
51	Drive trial	50	1	1	1	2
52	Trial and Final Steam dumping Floating	33, 34, 35, 40, 41, 43, 45, 46, 48, 49, 51	2	1	2	3

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