Identify Risk Areas, Schedule Modelling, Cost Analyzing - A Case Study for Incineration Plant @ Pune City

Aditya Dipak Dhanbhar[1], Dr. Navnath V. Khadake[2]

[1]*M.E. Civil Student, Imperial College of Engineering and Research, Wagholi, Pune, Maharashtra*
[2]*Ph.D. (Civil), M.B.A. (Project Management), FIE, FIV, FICA, MISH, Head of Civil Engineering Department, Imperial College of Engineering and Research, Wagholi, Pune, Maharashtra*

---***---

ABSTRACT - *Pune is 8th largest city in India and 2nd largest city in state of Maharashtra. City is home of many Automobile and Software industries. It is one of the fastest growing cities in Asian-Pacific region. City is experiencing great population growth rate in current decade. It is expected that population of the city hits nearly 8.5M by 2041. This results to tremendous amount of generation of Municipal Solid Waste. Such huge amount of MSW, nearly hundreds of tons generated every day also generates many issues for transportation, treatment and its disposal. Hence, to deal with this huge amount of waste, it is need of time to adopt new eco-friendly and economical solid waste management systems over conventional systems for city. Incineration method is one of the effective methods for solid waste management and implemented by many countries across the world.*

This research includes cost analysis, planning and scheduling of incineration plant for Pune city to minimize Solid waste problem for sustainable development. Also, this research extent to identify and quantify the area risk during construction of the plant. This study utilized the Program Evaluation and Review Technique/Critical Path Method (PERT/CPM) and Monte Carlo simulations for estimating the appropriate construction duration at the planning stage of an Incineration plant project. There was found an 85% likelihood of construction duration to be between 896 and 1096 days. From interviews with subject matter experts, the most significant risk factors were found to be labor strikes and construction safety incidents.

(Keywords: Incineration Plant, Planning and scheduling, PERT/CPM, Monte Carlo Simulation, Risk Assessment)

1. INTRODUCTION

Pune is 8th largest city in India and 2nd largest city in state of Maharashtra. City is home of many Automobile and Software industries. It is one of the fastest growing cities in Asian-Pacific region. City is experiencing great population growth rate in current decade. It is expected that population of the city hits nearly 8.5M by 2041. This results to tremendous amount of generation of Municipal Solid Waste. Such huge amount of MSW, nearly hundreds of tons generated every day also generates many issues for transportation, treatment and its disposal. But these problems have also provided a window of opportunity for cities to find solutions - involving the community and the private sector; involving innovative technologies and disposal methods; and involving behaviour changes and awareness raising for treatment of waste.

Today average MSW generation for Pune City is around 0.34 (kg/capita/day) and expected to increase up to 0.70 (kg/capita/day). Hence, to deal with this huge amount of waste, it is need of time to adopt new eco-friendly and economical solid waste management systems over conventional systems for city. Incineration method is one of the effective methods for solid waste management and implemented by many countries across the world.

This research includes cost analysis, planning and scheduling of incineration plant for Pune city to minimize Solid waste problem for sustainable development. Also, this research extent to identify and quantify the area risk during construction of the plant.

1.1 Objectives of study:

1. To carry out cost analysis for Incineration method as effective solid waste management method
2. To develop a schedule model to estimate typical construction duration using Critical Path Method and Program Evaluation Review Technique
3. To showcase the minimum and maximum duration required for construction of incineration plant using Monte – Carlo simulation and MS- Project
4. To identify and quantify the areas of risk during the procurement of construction of the plant.

1.2 Introduction to Incineration Process:

Incineration is the waste treatment process the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. In some cases, the heat generated by incineration can be used to generate electric power.

1.3 Block Estimate of Proposed Plant

The Cost estimates for the proposed Incineration plant includes:

- Capital investment for Pre-processing unit
- MSW Processing Plant
- Pollution Control Equipment,
- Continuous Emission Monitoring System
- Information Communication Technology
- Auxiliary Power Supply System and
- Allied Infrastructure.

Table 1.3.1 Block estimation of Incineration plant

Component	Description	Cost (Rs. Crores)
Component-A	1: Site & Peripheral Preparation including 2. Site Survey 3.Geotechnical Investigation, 4.Waste Physico-chemical Characterization Study 5.Site Clearance, Excavation, Filling & Compaction 6. Compound Wall 7. Pipeline & Pumping Station 8. Preparation of Eastern Peripheral area slope 9. Landscaping 10. Storm Water Drain	146.95
Component-B	Design including all approvals	28.64
Component-C	Pre-Processing Plant	138
Component-D	Processing Plant (Electric Power Plant) including Civil, Electrical, Mechanical, I&C, Water System, Construction, Supervision, Pollution Control Equipments, etc.	469.09
Component-F	Power Evacuation Line	21.17
Component-G	Process by-product Management and Disposal (Ash/ Sludge/ Rejects/ other) Plant	4.99
Component-H	Tests on Completion and Training	9.38
Component-I	Provisional Sums – General	5
Total (Rs. Crores)		**877.76**

1.4 Economics of the Plant

Incineration plant needs large investment. Therefore, cost and economics of plant plays important role. Availability of MSW, investment of plant, revenue generated through energy and payback period of investment are important element in economics of project. Some assumptions are required to proceed.

Those are given below: -

1) The MSW generated is 3000 MT/day

2) The incinerable matter present in the MSW generated is 89.6% i.e. 2688 MT/day.

3) Additive material coal is used as 20% of MSW

4) Collection efficiency of MSW is 100%

5) Electricity generated through incineration plant is provided for only industries at the rate of Rs10/unit.

Sr. No.	Description	Unit
1	Capacity	981120 T/Y
2	Output	
	Bottom Ash	295693.8 T/Y
	APC Residue	41397.132 T/Y
	Electricity for Sale	36500 MW/h
3	Investment	
4	Annual Capital Cost	877.76 Cr
5	Annual Revenue Energy Sale	5 Cr

Table 1.4.1 Economics of the plant

2. Planning and scheduling of the plant

2.1 Research Methodology

For this study, the development of the schedule and related risk factors included the following research steps:

Step 1 – First step of the research is to identify high risk block of activities that will cover entire construction process of the incineration plant. Selected activities are from literature survey for similar construction. These blocks of activities can be further used for planning and scheduling purpose.

Sr. No.	Activities
1	Boiler excavating to foundations
2	Foundations and concrete work
3	Boiler main steel
4	Miscellaneous steel and finish
5	Boiler pressure parts installation
6	Turbine building excavating to foundations
7	Discharge tunnel and foundation concrete
8	Main steel frame installation
9	Crane installation and testing
10	T/G base mat concrete
11	Pedestal and deck concrete
12	Bench mark and chipping
13	Sole Plate
14	Turbine generator installation
15	Electrical System
16	Chemical cleaning and cold clean up
17	Steam blow-out
18	Boiler and auxiliary system test
19	Firing test
20	T/G and auxiliary system test
21	Trial Operation

Table 2.1.1 Selection of high-level project activities.

Step 2 - Define three points of activity durations: From the project case studies, the most likely durations are taken.

Optimistic Duration: Optimistic duration is the shortest expected duration to complete the task.

Most Likely Duration: Most Likely Duration is the duration which the task can be completed considering the availability of the given resources, its productivity, and realistic resources. **Pessimistic Duration:** Pessimistic Duration is the expected longest duration within which the task can be completed. This process is as dictated by the PERT estimation method.

Step 3 - Using the three points of activity duration identified above, expected duration is calculated using following equation,

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

Where,

t_e is expected activity durations (in days)

t_o optimistic activity duration (in days)

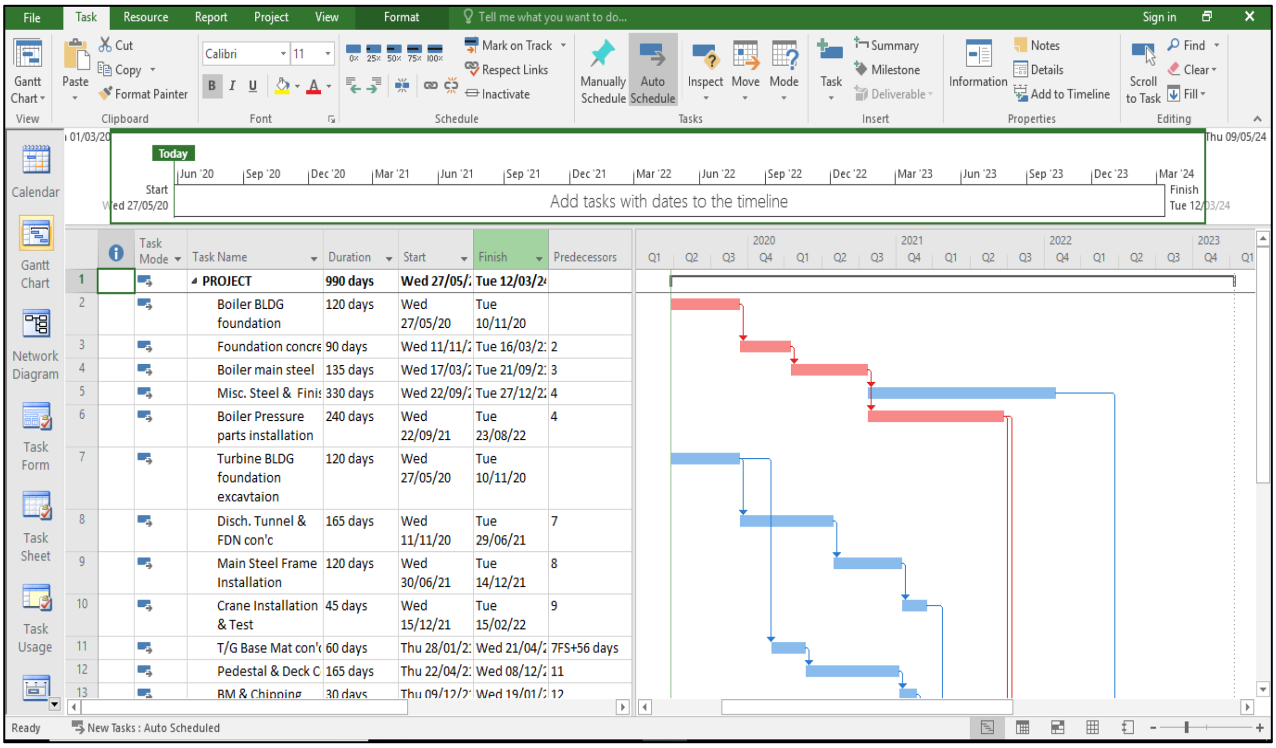
t_m most likely activity duration (in days)

t_p the pessimistic activity duration (in days).

Sr. No.	Activities	to	tm	tp	te
1	Boiler excavating to foundations	108	119	130	120
2	Foundations and concrete work	75	91	105	90
3	Boiler main steel	113	135	150	135
4	Miscellaneous steel and finish	320	328	350	330
5	Boiler pressure parts installation	215	237	260	240
6	Turbine building excavating to foundations	100	120	138	120
7	Discharge tunnel and foundation concrete	151	164	185	165
8	Main steel frame installation	108	118	137	120
9	Crane installation and testing	40	43	56	45
10	T/G base mat concrete	52	59	71	60
11	Pedestal and deck concrete	155	161	190	165
12	Bench mark and chipping	18	30	42	30
13	Sole Plate	10	12	20	13
14	Turbine generator installation	255	268	290	270
15	Electrical System	12	13	18	14
16	Chemical cleaning and cold clean up	10	14	22	15
17	Steam blow-out	15	18	22	18
18	Boiler and auxiliary system test	115	118	125	119
19	Firing test	28	31	37	32
20	T/G and auxiliary system test	25	29	30	29
21	Trial Operation	200	210	232	211

Table 2.1.2 Calculation Expected time schedule of the plant

Step 4 – Critical Path is Identifies using MS – Project: From the above three-point activity durations expected activity durations and in using MS Project scheduling software, the critical activities were identified.



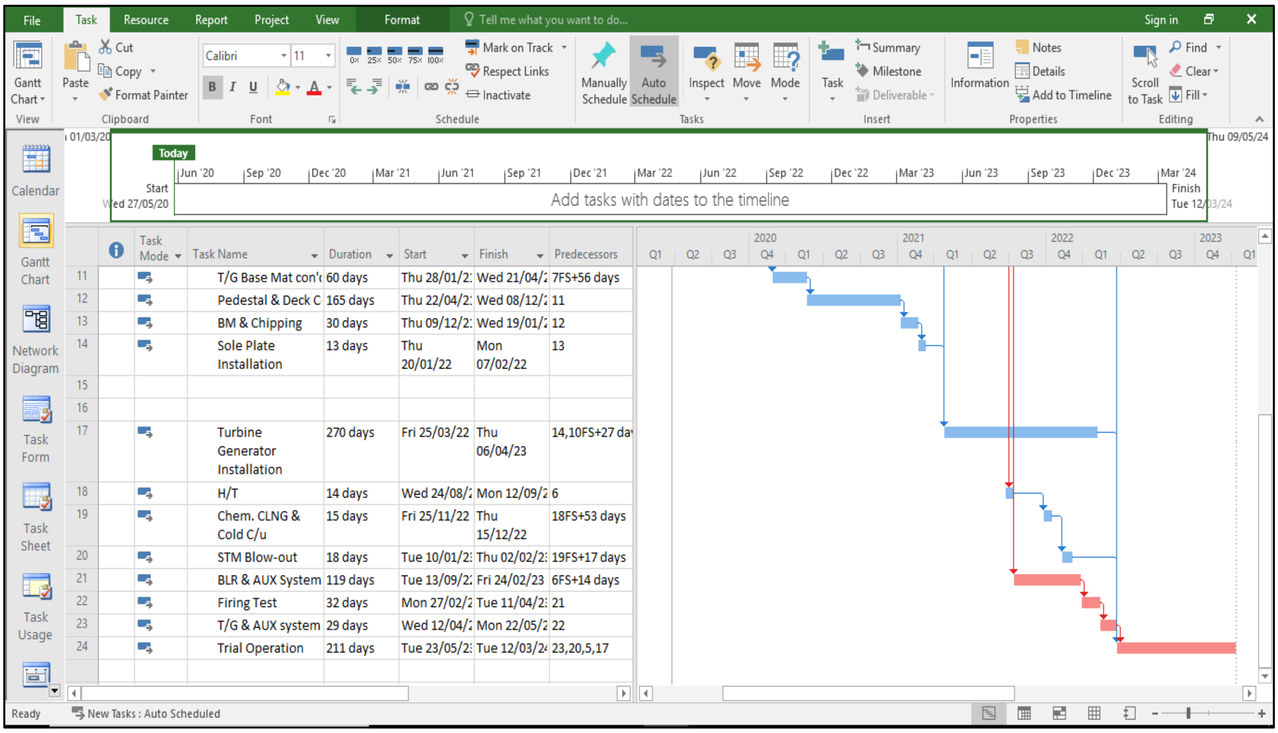


Fig. 2.1.1 Schedule for Incineration plant using MS-Project

Step 5 - Calculate Standard deviation using: The formula used in the PMBOK for standard deviation is simple. It's just pessimistic activity estimate minus the optimistic activity estimate divided by six. The problem is that this in no way shape or form produces a measure of standard deviation.

$$\sigma = \frac{t_p - t_o}{6}$$

Sr. No.	Activities	to	tm	tp	te	Std. Dev. (σ)	(σ²)
1	Boiler excavating to foundations	108	119	130	120	3.67	13.44
2	Foundations and concrete work	75	91	105	90	5	25
3	Boiler main steel	113	135	150	135	6.17	38.03
4	Miscellaneous steel and finish	320	328	350	330	5	25
5	Boiler pressure parts installation	215	237	260	240	7.5	56.25
6	Turbine building excavating to foundations	100	120	138	120	6.33	40.11
7	Discharge tunnel and foundation concrete	151	164	185	165	5.67	32.11
8	Main steel frame installation	108	118	137	120	4.83	23.36
9	Crane installation and testing	40	43	56	45	2.67	7.11
10	T/G base mat concrete	52	59	71	60	3.17	10.03
11	Pedestal and deck concrete	155	161	190	165	5.83	34.03
12	Bench mark and chipping	18	30	42	30	4	16
13	Sole Plate	10	12	20	13	1.67	2.78
14	Turbine generator installation	255	268	290	270	5.83	34.03
15	Electrical System	12	13	18	14	1	1
16	Chemical cleaning and cold clean up	10	14	22	15	2	4
17	Steam blow-out	15	18	22	18	1.17	1.36
18	Boiler and auxiliary system test	115	118	125	119	1.67	2.78
19	Firing test	28	31	37	32	1.5	2.25
20	T/G and auxiliary system test	25	29	30	29	0.83	0.69
21	Trial Operation	200	210	232	211	5.33	28.44

Table 2.1.3 Table 4.2 Calculation for Standard Deviation

Step 6 - To estimate the schedule using the PERT/CPM method, it is necessary to calculate the critical path. The critical path is the activities which constitute the longest work path for project completion. The activity relations were based on survey responses. The activities & their relations were input into MS Project software, using the most likely durations.MS Project output and critical path activities (bar chart durations shown in red)

Sr. No.	Activities	to	tm	tp	te	Std. Dev. (σ)	(σ^2)
1	Boiler excavating to foundations	108	119	130	120	3.67	13.44
2	Foundations and concrete work	75	91	105	90	5.00	25.00
3	Boiler main steel	113	135	150	135	6.17	38.03
5	Boiler pressure parts installation	215	237	260	240	7.50	56.25
18	Boiler and auxiliary system test	115	118	125	119	1.67	2.78
19	Firing test	28	31	37	32	1.50	2.25
20	T/G and auxiliary system test	25	29	30	29	0.83	0.69
21	Trial Operation	200	210	232	211	5.33	28.44
					990	**31.67**	

Table 2.1.4 Calculation for Standard Deviation for Critical Activities

Step 7 - Using the @Risk Monte Carlo software (Microsoft Excel 2016), simulated 1000 projects based on the software's value at risk assessment. depicts the results of this simulation and depicts the minimum project duration of 895.48 days, maximum 1095.58 months, and average 991 days. However, with this type of analysis, often the project duration range that is 85% likely is of interest.it is seen that that the shortest project is about 896 days, and the longest process is about 1096 days.

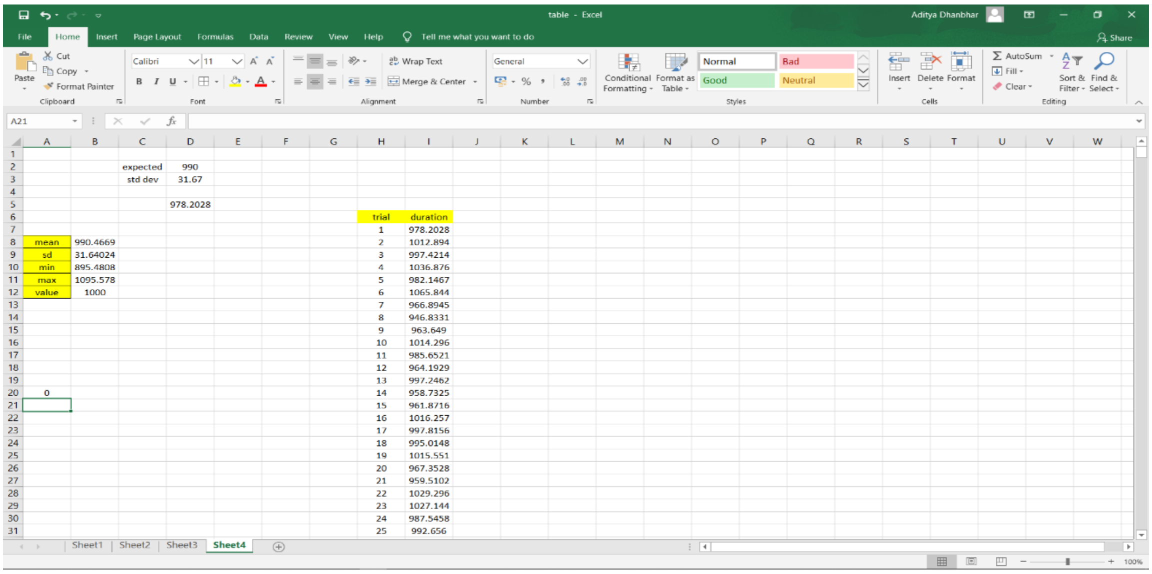


Fig. 2.1.3 Performing Monte-Carlo Simulation

2.2 Risk in Construction of Incineration Plant

Risk management has become an essential requirement for construction projects. Risk management process includes Hazard identification, Risk assessment and Risk control. Risk is assessed by Qualitative Methods and Quantitative Methods. Risk management is the systematic process of identifying, analyzing, responding to project risk, and it includes maximizing the probability, consequences of positive attributes minimizing the probability and consequences of attributes adverse to project objectives.

The key success indicators of construction management system(s) include completing the project with cost and time, within the planned budget and duration, and within the required quality, safety, and environmental limits. These goals are interrelated where each of them is affecting and affected by the others. An accurate cost estimating and scheduling should be sought in order to meet the overall budget and time deadline of a project.

2.3 Risk Factors for the construction of the Incineration Plant

The purpose of study is to review and compose the previous facts and discussions about risk factors and to provide a complete list of major sources of risk factors in the life cycle of construction projects based on extensive literature study.

2.3.1 Identify and Quantify Risk Factors

Identify risk factors and influence: Finally, from the survey and interview results, risks and their impact, influence, and priorities were identified. To quantify the risks for comparison, the multiplied the probability by the rated impact, both scored from 0 to 1.

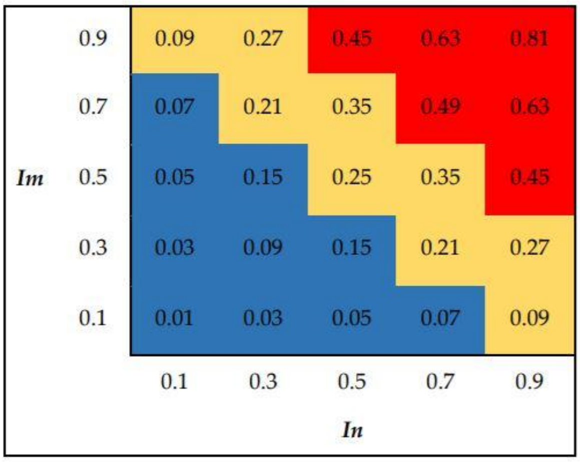


Fig. 3.2.1 Calculation for Risk Factors

If the importance of a risk and the influence on the project are both low, the risk is regarded as a low risk, and the opposite case will be a high risk. The vertical axis indicates the probability of occurrence (importance) and the horizontal axis represents the impact of the risk (influence) on the project. The intersection of possibilities and influences is calculated by multiplying the numerical values of the two criteria called the risk score. The score ranges are as follows: from 0.01 to 0.15 for Low Risk, from 0.15 to 0.35 for Moderate Risk, and from 0.45 to 0.81 for High Risk.

Risk Impact = Importance × Influence

2.4 Results

The last research goal is to identify and quantify the potential risk factors existent in Incineration plant construction. The associated scores for the risk factors based on the surveys shown as below:

Risk Factors	Importance	Influence	Risk Impact	Degree of Risk	Priority
A labour strike	0.88	0.9	0.79	High	1
Occurrence of safety accident	0.76	0.7	0.53	High	2
Social issues of local	0.58	0.54	0.31	Moderate	3
Shortage of local labour	0.54	0.52	0.28	Moderate	4
Lack of technical ability of subcontractor	0.52	0.6	0.24	Moderate	5
Occurrence of design change	0.44	0.48	0.21	Moderate	6
Error of scheduling equipment operation	0.42	0.34	0.14	Moderate	7
Error of calculating material quantity	0.38	0.34	0.13	Moderate	8
Shortage of transportation facilities accessibility	0.38	0.32	0.12	Moderate	9
Delayed payment of construction expense	0.3	0.3	0.09	Low	10

Table 3.3.1 Calculation for Degree of Risk

3. Conclusion

1. For the treatment of huge amount of municipal solid waste Incineration method is the best method and had potential to produce **36500 MW/h of electricity annually**. Block cost estimation for the construction of Incineration plant is **877.76 Cr** which could recover by selling Electricity produce by plant. Hence it is Feasible to construct incineration plant for effective solid waste management system for Pune City.

2. Critical Path is found out for construction of plant as follows:

Sr. No.	Activities
1.	Excavating to foundations
2.	Foundations and concrete work
3.	Boiler main steel
4.	Boiler pressure parts installation
5.	Boiler and auxiliary system test
6.	Firing test
7.	T/G and auxiliary system test
8.	Trial Operation.

One needs to be very careful while executing these critical activities to complete the project in gives schedule as these activities have 0 float. It could affect whole schedule of construction of the plant.

3. Using the @Risk Monte Carlo software (Microsoft Excel 2016), simulated 1000 projects based on the software's value at risk assessment. The results of this simulation is **minimum project duration of 895.48 days**, **maximum 1095.58 days**, and **average 991 days**. Probability to complete the construction of the project into given range i.e. 896 – 1096 days is **85 %.**

4. From these factors, A labor strike and Occurrence of safety accident these two factors are most important and have high degree of risk. So, during the construction of the plant contractor should take precautions so that this factor does not affect the schedule of construction.

References and Bibliography

1. **A Study on Risk Factors Involved in the Construction Projects** by Surabhi Mishra, Brijesh Mishra – (International Journal of Innovative Research in Science, Engineering and Technology Vol. 5, Issue 2, February 2016**)**
2. **Simplified program evaluation and review technique (pert)** by Wayne d. Cottrell – (journal of construction engineering and management / January/February)
3. **Risk assessment in construction schedules** by B. Mulholland and J. Christian (journal of construction engineering and management)
4. **Project Management Information Systems for Construction of Thermal Power Plant: A Case Study with Special Reference to National Thermal Power Corporation Ltd., India** by Dr. D. K. Choudhury (Dean & Professor Gitarattan International Business School, Delhi) **–** (International Journal of Engineering Research & Technology (IJERT) **-** Vol. 3 Issue 3, March – 2014
5. **Developing a Construction Duration Estimation Model to Ensure the Safety in Apartment Housing Construction Sites** by Jin Ho Lim, (KSCE Journal of Civil Engineering volume 22, pages2195–2205(2018))
6. **Development of waste-to-energy (wte) project at deonar, Mumbai feasibility & detailed project report** by Tata Consulting Engineers Limited **-** Document No. TCE 10176A-2024-DPR-R1 **-** October 2016
7. **Solid Waste Management in PCMC (3R‟s Principle)** by Niraj Burge, Sunil Gangurde (U.G. Student, Department of Civil Engineering, Rajarshi Shahu College of Engineering, Tathwade, Pune-411033, Maharashtra, India) **-** International Journal of Science and Research (IJSR) **-** May 2015
8. **Feasibility study of waste incineration plant in the city of Misurata- Libya** by Ibrahim Badi* , Mohamed Sawalem, Ali Shetwan (Industrial Engineering Department, College of Industrial Technology, Misurata, Libya) **- International journal of engineering sciences & research technology - February, 2016**
9. **Feasibility study of power generation from municipal solid waste of Haridwar city** by SIDDHARTH JAIN∗ and M. P. SHARMA (Int. J. Chem. Sci.: 6(4), 2008, 1920-1941)
10. **Improve the calorific value of Municipal Solid Waste by Adding Additive Material for Incineration Process",** by Aditya Dhanbhar, Shubham Ghatage, Shubham Pawar, T.S. Khambekar (2018), (IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 2 Ver. V (Mar. **-** Apr. 2018), PP 77-82)

- **Bibliography**
- https://www.pmc.gov.in/en
- www.egovamc.com
- www.swachcoop.com