Innovations

Application of Monte Carlo Simulation in Risk Analysis of Combustion Inspection Project Cost

Dr. Enyinna Gregory. C
Department of Project Management Technology and World/ NUC Centre of Excellence in Sustainable Procurement, Environmental and Social Standards, Federal University of Technology Owerri, Imo State, Nigeria
Dr. Uche. U. Moneke
Department of Project Management Technology, Federal University of Technology Owerri, Imo State, Nigeria
Dr. Uche, Ijioma
Brandenburg University of Technology, Cottbus-Senftenberg, Germany
Uba Akadike
MSc Candidate, Department of Project Management Technology, Federal University of Technology Owerri, Imo State, Nigeria

Corresponding Author: **Enyinna, Gregory. C**

Abstract
This study applied Monte Carlo Simulation in carrying out risk analysis of general electric (GE) Frame 9E Gas Turbine Prepared for Combustion Inspection at Transcop power Limited (TPL) with the aim of modelling the company's combustion inspection project cost. Secondary data was acquired from the company for simulation using MATLAB®, Python®, @Risk® of Palisade Corporation which is an add-in program for Microsoft® Office Excel, and the Crystal Ball of Oracle®. That made it possible to define probability of continuous stochastic variable as variable value that is included in a specified interval using Monte Carlo Simulation principles. Data were acquired on monthly basis for the years 2014 to 2020 which made it possible for us to ascertain these facts, from Simulation result indicated that it is possible to carry out any of the three turnaround projects on GT4 to GT13 with a project cost of 255 million naira when adequately managed, while 580 million would be sufficient for GT15 to GT20. Thus, risk analysis on combustion inspection project cost helped facilitate efficient process of turnaround maintenance project without delaying the process which can eventually affect the efficiency of the mode of operations of the Turbine or create a possible condition of equipment breakdown. This process through the aid of Monte Carlo risk simulation created high accuracy for risk management of combustion inspection project cost at Trancop power Limited.

Keywords: *Risk Management, Analysis, Turnaround Project, Monte Carlo Simulation, Project Cost, Combustion Inspection.*

1: Introduction

The Increasing challenges of project complexities has necessitated unique nascent developmental strategies that could model possible uncertainties likely to be experienced during the processes of project development. This is expected to be a proactive measure that could be incorporated for a successful development and implementation of project planning and control. The expected reliable model results is anticipated to be beneficial in project development life cycle process as well as possible turnaround

project and can be obtained through the development of risk simulation with the help of Monte Carlo risk modelling strategy. This could be explained from previous experiences that displayed probability of successfully implementing deterministic project schedules of very low budgets. Though modelling or simulation could be employed when complex situations arise using probabilistic analysis. Probability distribution for each risk involved in combustion inspection project cost would be specifically identified with a combination of its effect being put into consideration but in the case of discrete estimates, decision trees can be put into used.

In consideration of the accuracy of results yielded from the application of Monte Carlo risk model, it could function as a common probabilistic method used in risk simulation, using random calculation of values within a specified probability distribution. Three estimates are frequently used that include: minimum or optimistic estimates as well as, mean or most likely and maximum or pessimistic estimates. It is expected that the overall outcome for the combustion inspection project cost would be derived from a combination of values selected for each of the risks. The calculation is expected reoccur as many times as possible, which is usually carried out thousands of times in most experiments so as to obtain the probability distribution of outcome of the project.

Probabilistic time analysis, could also be carried out using critical path method network, for modelling project schedule and the same method can also be used for probabilistic cost analysis of combustion inspection project cost especially, when cost estimate is broken down into same categories or activities like the schedule and while cost risks are related to time risks (APM, 2012).

Combustion Inspection Project Cost is basically necessitated to be analysed for verifying the level of price fluctuation over the years so as to identify the drivers of fluctuation in other to have the capacity to monitor project cost possibility of escalation that may hinder or prolong the time schedule for maintaining turnaround project. Thus, According to Energy sector management assistant program (ESMAP, 2009) Power plant projects, infrastructural projects, as well as crude oil-related projects have triggered appreciable uprising in demand for boilers, equipment that rotates, pipes, steel for structures, concrete and electrical equipment. Within the past four years, there has been increasing global demand in cost of equipment and material in the power sector. This could be attributed to high increases in the demand of labour relating to manufacturing and fabricating equipment as well as raw materials. Records show that only in 2006 -2008, energy projects that were funded by World Bank was 30–50 percent more than the actual estimated cost that necessitated more funding for the project, reducing the project scope, or delays in schedule. These delays have high cost implication to clients of the financial institutions because they depend on timely completion of projects in other to produce the quantity of energy for the satisfaction of market demand. Escalations in cost of combustion inspection project materials are also triggered by conditions of economic downtime that may bring about rise in cost of raw materials as well as more demand of wages by possible staff that would carry out the duties of combustion inspection project. (ESMAP, 2009) Furthermore, risk analysis of combustion inspection project cost requires the application of Monte Carlo simulation, in its proper modelling that will create room for justification of treatments of risk or response plans as clearly an adequate condition for planning any project with capacity to conduct risk analysis. (Besner & Hobbs, 2012] identified some major conditions assumed as conditions for successfully setting up a project like, continuous management of risk and Monte Carlo simulation that requires worst case and best case seniors of cost estimates and activity duration estimates. In consideration of use of Monte Carlo risk simulation for combustion inspection project, the following decision flow system should be followed;

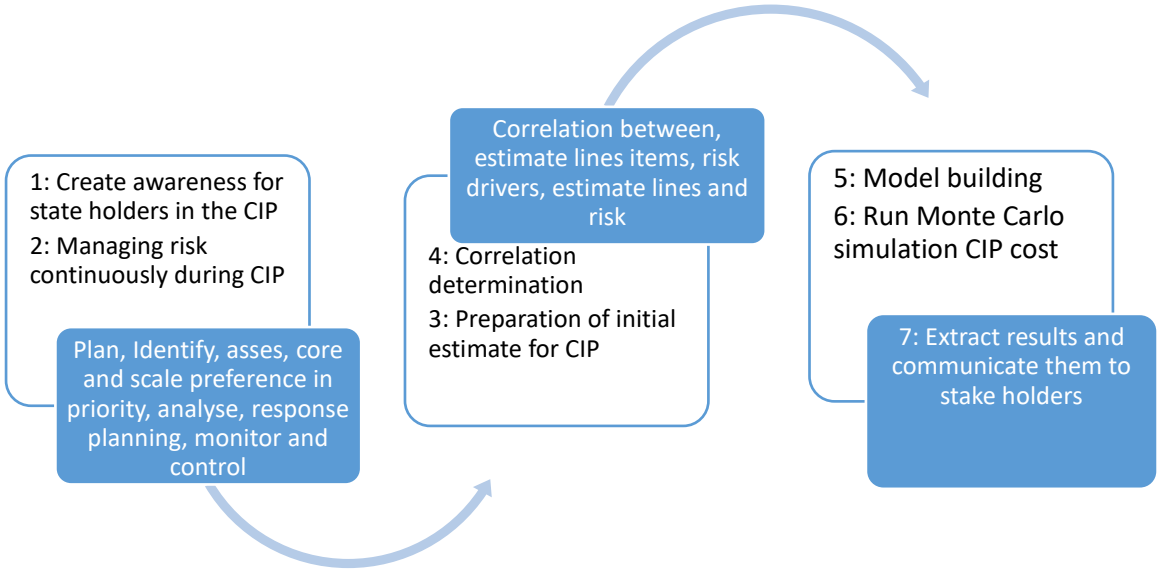

Figure 1: Decision flow system in application of Monte Carlo simulation for Combustion Inspection Project (CIP)

Risk assessment and analysis on combustion inspection project cost, is aimed at drastically minimizing loses incurred in the process of combustion inspection, in other to productivity as well as creating opportunities for profit maximization via Improved Productivity.(Dave, 2019) acknowledged that, regular failures of equipment likewise unexpected and unplanned shutdowns cost accrue some billions of dollars as industrial cost annually. In trying to mitigate the risk association with combustion inspection project cost, proper management of the process would verify losses contained in the process which is crucial within all industrial facilities from organizational, engineering, and economic dimensions. This becomes necessary because when an inspection project engineer receives 40 work orders in one day with limitations in time, budget, tools as well as labour, He needs to prioritize and organize the workload. (Dave, 2019) also indicated that, two over three of these costs associated with inspection project may be traceable to static equipment failure. The reason for these failures could be seen from two different dimensions, which include: application of obsolete time-based inspection for turbine industry assets where Engineers may carry out inspections that are not needed at the particular plant but ignore very important inspections. The second one is, application of wrong methods of combustion project inspection. These would produce poor data and would never be supportive to result oriented risk management processes. The resultant effects of these processes would be unexpected increase in costs, since there is a high tendency of failure of combustion project equipment, negation in environmental impact compliance as well as negative impact on health and safety of personnel.

Risk management based Equipment project inspection (RMBEPI) may have helped in preventing unplanned short down of machines in our industries, it is also necessary to apply risk management based inspection in estimating, analysing and evaluation of combustion project cost to prevent unnecessary loses in the process of procurement of combustion inspection project materials at very high cost in terms of goods and services needed for inspection of combustion projects. Risk management based project inspection creates schedules for inspection from dimensions of possibilities of failure of equipment (PFE) and resultant effects of such failure (REF). Possibilities of failures and resultant effects of such failure when added together would identify the machine that should be given most inspection attention in order to minimize unnecessary financial investment on equipment that does not require much attention.

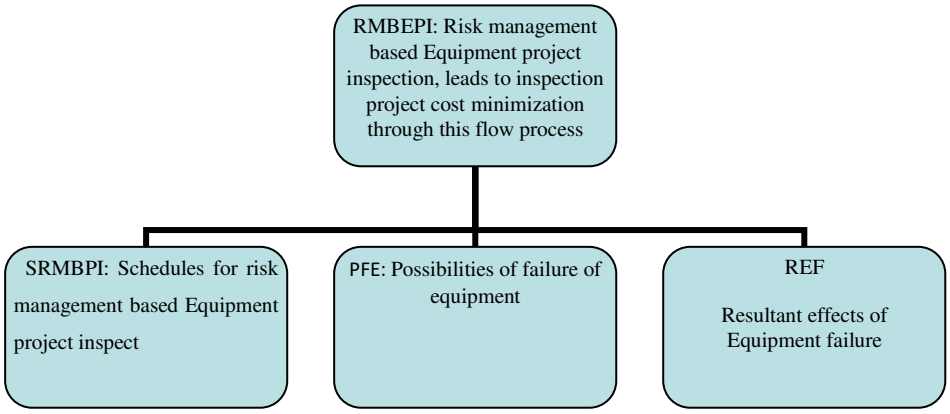

Figure 2: Risk management flow diagram for cost minimization in Equipment project inspection

Risk based Equipment project inspection would reduce the overhead cost of executing combustion inspection projects because it allows us to properly allocate available financial resources in procurement of services of experts and best equipment, needed for all inspection projects at a minimal standard that would allow lowest cost on investment of such projects. Thus this research seeks an avenue of reduction in cost of maintenance of turbine's combustion through inspection process. Therefore, (Alex, 2017) specified that increase in turbine maintenance intervals will bring about reduction in cost of carrying out maintenance. He also stated that, hot gas path (HGP) inspection for Siemens V84.2 is required at 25,000 EOH interval or on six years interval. It is also required that major inspection will be carried out at 50,000 EOH intervals or at 12 years. The units at the Holden plant had accumulated around 10,000 EOH during 12 years interval. Thus this organization wanted to investigate, if extending inspection intervals will not affect performance as well as turbine's reliability. This cannot be achieved without verifying how favourable and beneficial the cost implication will be before embarking on such project.

Thermenergy [2021] indicated that combustion inspections are carried out while the unit is shut down to change out and service parts of the gas turbine after it has functioned for a stipulated time of about 8,000 or 12,000 hours which is the expected Operation period. Such inspection allows engineers to ascertain the state of health of the gas turbine unit for possible repair or replacement of any of its compartments that needs attention. Thermenergy provided much needed support for pre-outage inspections and planning, as well as the execution of the Combustion Inspection. Since Thermenergy carried out field Service for Engineering support towards critical modifications to the Gas Turbine unit and other very important tests as well as inspections on plant equipment balance and support systems. It will also be necessary to analyse the associated risk to cost implication of such functions especially the combustion inspection cost.

Combustion inspection project cost would include the cost of procurement of goods, services and works that would support the process of combustion inspection project. (Beroe, 2021) stated that procurement is the identification and implementation of certain steps by business to ensure they can acquire goods and services to meet their requirements and achieve their objectives which is important because of its direct impact on how much a business can save when a business access the procurement process, it ensures their goals will be met. Changes can be made in the process when it is not working as planned.

When products crop up for the business as procurement main aim is to boost efficiency. Business must ensure they are driving maximum value for their process and value for money. Different businesses would different procurement processes since they have different goals. The process flow will involve creating a purchase order that details all procurement requirement specifics.

Figure 3 below shows diagrammatical concept of procurement process for combustion inspection project cost.

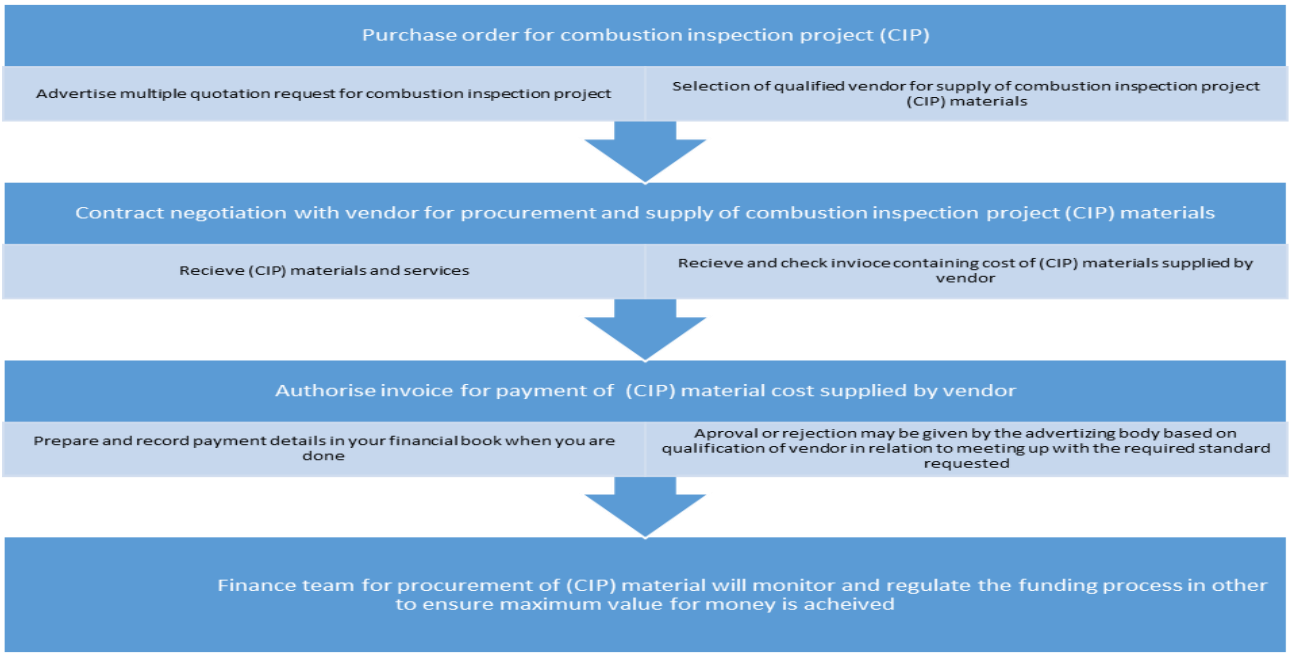

Figure 3: Diagrammatical display of procurement process for combustion inspection project cost.

Risk analysis of combustion inspection project (CIP) cost cannot be carried out without considering the different components of the system with cost implication required for its efficient functionality. Therefore cost is considered prior to combustion inspection planning so as to facilitate the planning process for efficient inspection of the process. Furthermore, cost of advertisement of quotation request is also necessary. Another area cost should be considered is in the management of process of selection of vendor. There is also need to consider the cost of both combustion inspection materials and human resources. Thus cost of acquisition of experts that will manage the combustion inspection project. It is also important to consider cost of implementation of combustion inspection report peradventure there is need for maintenance or replacement of parts of the system for an upgrade or extending of life of the combustion project system. See Figure 4 below for the considerations for cost analysis.

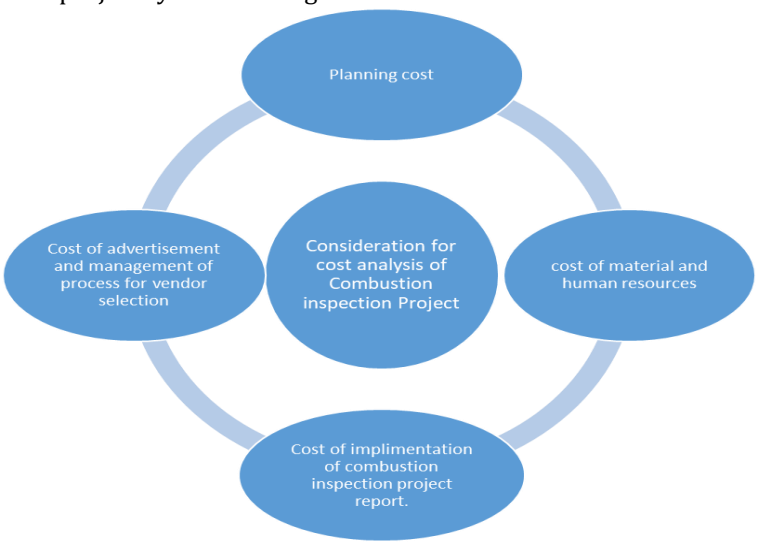

Figure 4: Considerations analysis of combustion inspection project cost

Though, (Williams et al, 1998) identified method of risk classification which was dependent on the environment and they include; Physical environment; social environment; political environment; operational environment; economic environment; legal environment and cognitive environment.

2: Materials and Methods

GE Frame 9E gas turbine, was prepared for combustion inspection project at TPL because major maintenance inspection is carried out on any of the turbines within average of 2 years before any other turnaround project is done on it. Therefore for the purposes of keeping to the time schedule for turnaround projects it became necessary to carry out risk analysis of the cost of combustion inspection project that is most cost demanding because of larger scope of maintenance job usually within the system. Figure 5 below, displays the image of GE Frame 9E gas turbine prepared for combustion inspection project at Transcop power Limited (TPL).

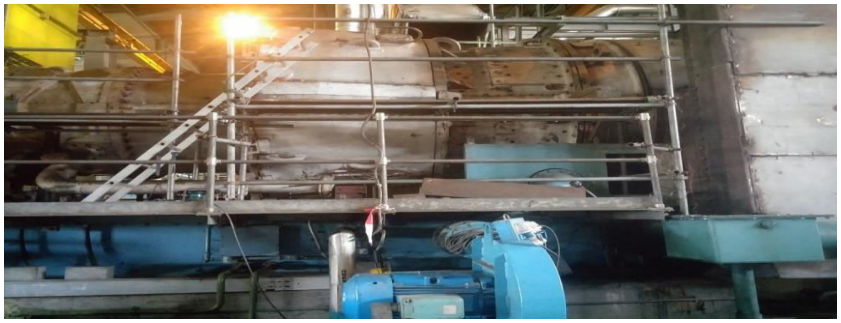

Figure 5: General Electric (GE) Frame 9E Gas Turbine Prepared for Combustion Inspection at TPL

Secondary data was acquired from Transcop power Limited (TPL) for cost of combustion inspection project for risk analysis and effective risk management.

According to (Purnus & Bodea, 2013) effective risk management there should be a consolidated basis project based decision-making process that has the capability of creating much valuable benefits that would save cost improve stakeholders engagement towards better change management.

Risk analysis, of combustion inspection project cost helps project managers to initiate a deeper understanding of cost of carrying out combustion inspection project and its associated financial difficulties. For us to effectively achieve such, we applied some techniques will provide either qualitative information for risk prioritization or measurement of quantitative risk with consideration that Qualitative techniques are easier to apply with less effort. Thus, this Qualitative risk assessment manifest as often sufficient method for rank-ordering risks, which would allow us to select the most significant ones. This concept came from (Anastasios, 2015). Furthermore, Quantitative methods is targeted at achieving greater precision, thereby revealing more about each risk with high capacity to provide data on the absolute extent of risks and permits us to give schedule estimate as well as budget reserves required for risky projects via mathematical analysis. (PMI, 2013) disclosed that quantitative risk analysis is the process of numerical analyses that effect risks that is identified on overall objectives of combustion inspection project and also gives much support for decision making so as to reduce project uncertainty. Therefore, the concept of knowing the risk associated with combustion inspect project cost, Identification of the risk and mitigating the risk via Monte Carlo simulation using MATLAB®, Python®, @Risk® of Palisade Corporation which is an add-in program for Microsoft® Office Excel, and the Crystal Ball of Oracle®. Hence, there was a possibility to define probability of continuous stochastic variable as variable value that is included in a specified interval. In this regard, the distribution is represented by a curve, and the probability determined by evaluation the area under such curve between the margins at intervals of x-axis (Purnus & Bodea, 2014).

The software used for this analysis produces much cases until a definite number of trials are achieved. The repetitions are done severally in hundreds or thousands time for us to reach a logical assumption for our expected value. The simulation is carried out in the following sequence: (a) Sampling of probability distributions that shows a representation of numerous random probabilistic variables. (b) Replace values of trials with random variables of the model.

(c) Save predefined value, like cost (d) Go back to the first step and restart the number of repetitions until outcome becomes accurate enough. (e) Result Analysis.

3: Results

Table 1 below, displays the values of cost of conducting Combustion inspection project cost in Millions of Naira (MN) that were used in carrying out risk analysis of the project cost using Monte Carlo Risk principle for development of models that reflected as simulations for combustion inspection project Cost This values were monthly cost implications of combustion inspection project from the year, 2014- 2020 calculated in Millions of Naira (MN).

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Table 1: Cost of conducting combustion inspection projects in Millions of Naira

Monthly Project Cost (MN)	Year 2014	Year 2015	Year 2016	Year 2017	Year 2018	Year 2019	Year 2020	Total
January		232			650			882
February					205	350		555
March					267	208		475
April	130	215						345
May	430					270		700
June					750			750
July			200				202	402
August	304			305		576		1185
September		207	210					417
October			212					212
November						280	900	1180
December				335				335

These figures were collated as secondary data from general electric frame combustion inspection project for Transcop power limited, displaying the cost of carrying out combustion inspection project between the years, 2014 to 2020 at different months of these above years. Figure 6 shows the graphical representation of the table above.

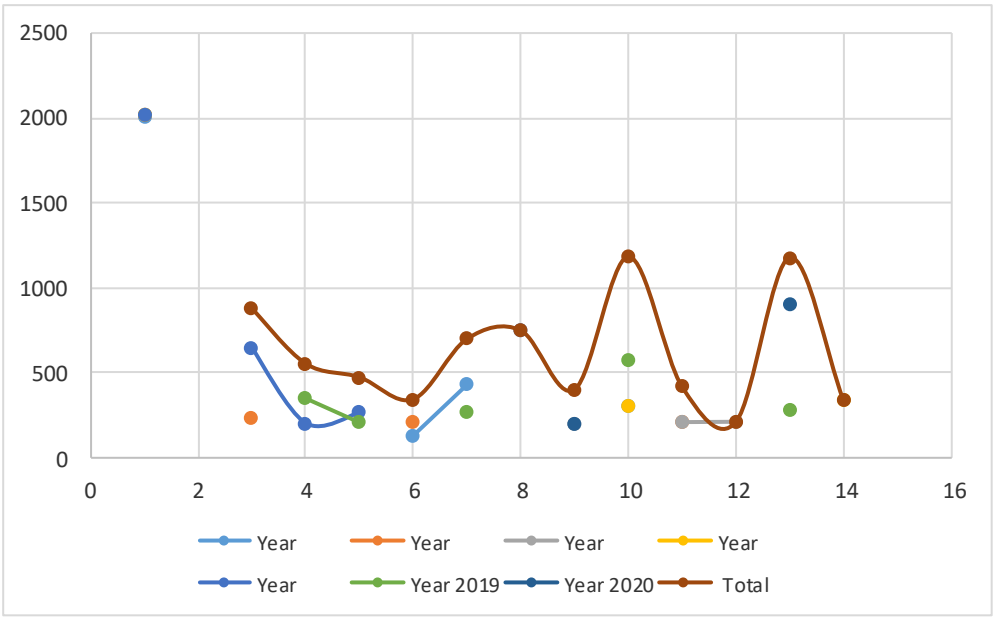

Figure 6: Graphical representation of cost of combustion inspection project 2014-2020

4: Discussion

4.1: Monte Carl risk analysis

MATLAB 2020 software by Mathworks® was used for combustion inspection project cost risk analysis that was used for running the simulation which showed that we reached significant point of analysis and interpretation of the results hence, the probability density function of the normal distribution for the three Inspection projects are displayed in details below.

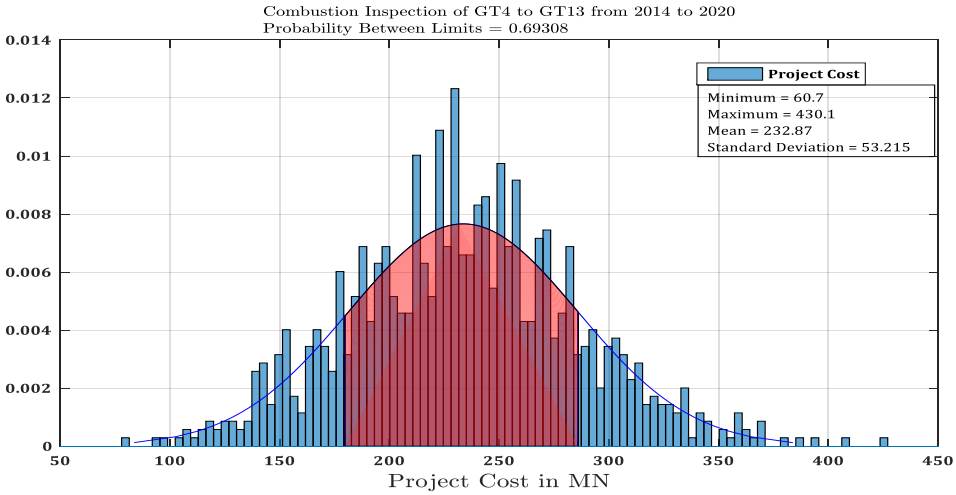

Figure 7: Combustion Inspection Project Cost for GT4 to GT13

The simulation result in figure 7 above shows that a larger proportion of combustion inspection projects for GT4 to GT13 would be successfully executed with a project cost between 180 million Naira to 280 million Naira. Provided other parameters are adequately managed. This is clearly seen from the area of the shaded portion under the normal distribution curve.

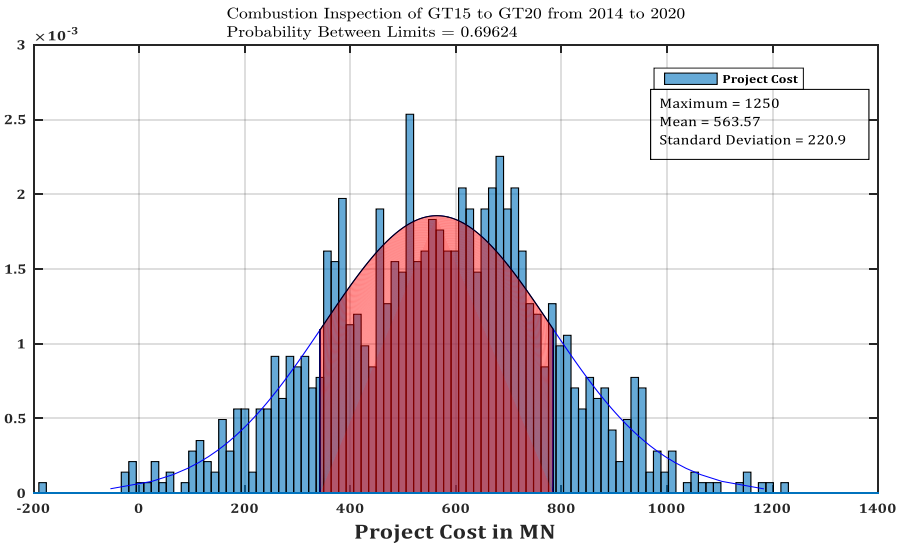

Figure 8: Combustion Inspection Project Cost for GT15 to GT20

The simulation result in figure 8 above shows that a larger proportion of combustion inspection projects for GT15 to GT20 would be successfully executed with a project cost between 350 Million Naira to 780 Million Naira respectively provided other parameters are adequately managed. This is also clearly seen from the area of the shaded portion under the normal distribution curve. The large project cost requirement for GT15 to GT20 is simply because these machines are larger in size, with more advanced technology. Thus, any project manager that plans to carry out this project with a cost outside this range will be faced with a high risk that may lead to wastage, project failure and cost overrun.

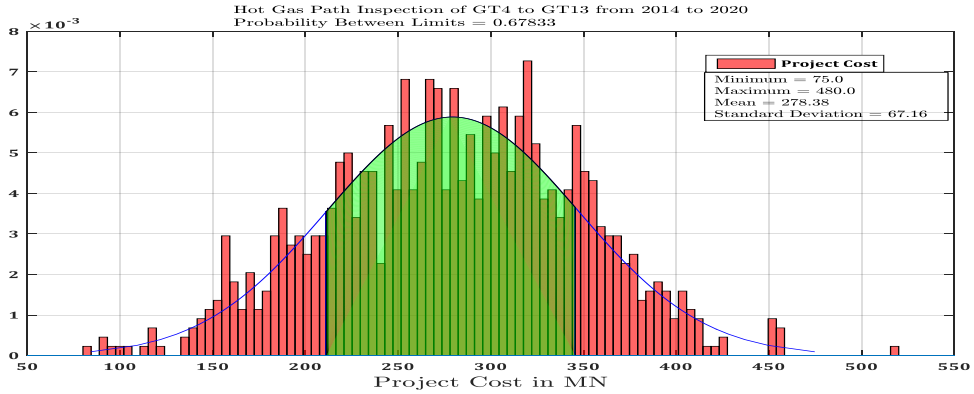

Figure 9: Hot Gas Path Inspection Project Cost for GT4 to GT13

Figure 9 above shows that TPL should plan to spend between 230 Million Naira and 340 Million Naira for HGPI on GT4 to GT13 in order to get an optimal power output after the turnaround project. Planning beyond this may be over budgeting and unrealistic.

5: Conclusion

This study covers the identification and analysis of the risks associated with cost of combustion inspection project for in view of turnaround maintenance project (shutdown) at TP. Scientific and numerically robust method of Monte Carlo simulation, was applied with in-depth approach which help us to achieve risk analysis of the combustion inspection project cost via strategic risk management approach. It was discovered that simulation outputs had variations that were dependent on the different sources of uncertainties in the input variables. This help us to create models using MATLAB 2020 of

Mathsworks® which gave us the deterministic data necessary for combustion inspection project cost Risk identification and analysis, using information gathering techniques from expert judgments and historical data from the company (TPL) in order to identify possible risks associated with the project cost which is high Project Cost of combustion inspection project. After running the simulation, the significant point of analysis and interpretation of the results was reached, with probability density function of the normal distribution showing that the three combustion inspection projects all have their specific mean and standard deviation peculiar to each project and turbine class. Simulation result indicated that it is possible to carry out any of the three turnaround projects on GT4 to GT13 with a project cost of 255 million naira when adequately managed, while 580 million would be sufficient for GT15 to GT20.We therefore conclude that it is very necessary to carry out risk analysis on combustion inspection project cost to facilitate efficient process of turnaround maintenance project without delaying the process which can eventually affect the efficiency of the mode of operations of the plants or create a possible condition of equipment breakdown. This process will be added through Monte Carlo risk simulation as a method of high accuracy for risk management.

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Corresponding Email: ***pycongregco@gmail.com***