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Sustainable Resource Optimization in Construction Projects to enhance Safety Protection in Oil & Gas Installations Conforming Standards

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Abstract

The Fatal accidents are rising every year during construction of projects in oil & gas industries. The safety during Construction Project execution at each stages results in saving precious lives & property enhancing capital costs. The Project management inculcates cost optimization considering efficient utilization of resources The risk management at each stage can be resolved by specific technological advances made in Project Management. Many approaches have been proposed for optimizing the cost and time which may compromise the safety aspects. The paper proposes a framework to assist the project managers for optimizing the resources and time period by evaluating the safety in each stage minimizing the hazard and risk associated with construction of projects. The simulation- based study by CPM & PERT is carried out for construction project of Oil & Gas production installation to demonstrate the practical applicability of model in achieving the targets of zero accidents at site and safe construction project targets. The inferences depicts the safety management during project execution at actual work site helps to save precious life from serious/fatal injuries and reduce downtime of project maintaining Process safety management.

Keywords—Project Management, Resource allocation, Cost, Time, Construction projects, CPM, Project Scheduling

I. Introduction

The Fire safety protection systems are required in various oil & gas installation PSU (Public Sector units) & private entities in order to control fire & explosion accidents resulting in disasters. The Fire systems such as fire header, hydrant, monitor, sprinkler, drencher, foam pourer, rim seal protectors are designed as per OISD standards 116,117 & 189. (Oil India Safety Directorate, Ministry of Petroleum & Natural Gas) considering the hazards & risk of oil & gas leakage, fire & explosion in installations. [1]

The fire safety project execution is more complex in now days and the decision making has become more complicated due to various alternatives, uncertainty and cost of making serious errors. It is difficult to always go for trial and error approach in decision making. More effective tools and techniques like PERT, CPM & Project Management Software of operational research for managing projects are available for handling schedules. [2]

The construction/revamping requires preparation for resource planning. The scheduling & resource allocation reduces the cost /budget & make it feasible to achieve the target deadlines. The PERT & CPM analysis of Fire protection projects in running installations may also reduce the downtime of shutdown in plants/installations & reduce the losses.[3]

Issues affecting the effectiveness of project management are problems with communication, control, competence, culture, and complexity. Recommendations using agile ways of working and engaging teams in different activities for success. [4] By choosing how to schedule construction managers highlight the need for fewer downtimes and better crew members. Surveys involving 74 managerial staff were carried out to develop tools that would be useful for construction managers. Using rapid intervention, project managers can make sure the project completion is on schedule and does not exceed the budget.[4]

Uncertainty in projects requires robust scheduling tools and corrective actions and their integration is emphasized. Project scheduling remains key to effective project planning and integrating AI techniques for better forecasting. Project scheduling techniques, Resource allocation methods, Risk analysis techniques, Statistical control charts, Simulation models, Earned Value Analysis (EVA) for monitoring are the areas of concern [3]

II. Literature Review

The activities in a project are critical activities where the timely completion is achieved. The network diagram predicts the Net cost of project by following the cost of each activity on critical path. [5]

For project planning the decision-making problem is very crucial. However, the methods and techniques are reviewed frequently over decades to solve these problems. Various problems arise due to decision making such as project representation, project scheduling, Risk Analysis, resource allocation, Cost and time performance evaluation, Safety at site, Budget issues, Cash flow forecasting, timing of various targets and others. [3]

The benefits of reducing time and better collaboration through agile project management will scale to larger projects preferably in critical safety industries. The analysis

for resistance to adopt agile project management is must for identifying the regulatory constraints and other barriers. Four factors – Organizational, Technological, Behavioral, Regulatory are assessed to identify the problems and find solutions to large scale agile project management in safety critical industries. [6]

In construction industries the perspective of experience first line managers and construction workers provides preconditions and components of high safety standards in construction industry Major characteristics are segregated in categories which are identified for work safety precondition.

a) project characteristic and nature of work which set the limit of safety project management .b) organization and structure having sub categories work role procedure planning and resources. c) norms collective values and behavior with sub category culture and climate corporation and interaction) competence of individual and attitude with sub category in knowledge ability and experience. [1]

The effective process planning in construction work area lead to optimization of resources. The productivity of construction operations studied in North America found that productivity of construction worker is reduced between 40% to 60% due to congestion.[7]

The congestion at work area are generated by causes such as management decisions, Safety concerns, improper activity sequencing , irregular flow of materials, poor onsite communication and excessive pre fabrication at work place. The safety concerns have weightage of 4% considering the utilization of time schedules. The attitude towards safety procedures and understanding the potential hazards to avoid minor accidents and near miss is of prime concern. [7]

The practical with adaptive assessment approach is used for determine leading causes / factors of low productivity in construction industry. The distribution of 915 factors is categorized into regional and productive dimensions through Pareto and Frequency analysis techniques considering interdependence of introduced benchmarks. Out of 915 the Safety & Project related factors having weightage of 43, depicts significant impact on construction project activities. [8]

Engineer-to-Order (ETO) systems require extensive design and engineering post-order. High coordination is needed, leading to non-value-added activities and increased lead times. Non-compliance with deadlines is a significant issue, termed as term loss or waste.[9]

Value Stream Mapping (VSM) is adapted for ETO but struggles with multiple product routings. VSM limitations in quantifying losses in ETO production. Existing tools are too specific or simplified for effective loss quantification in ETO. Manufacturing Critical-path Time (MCT) is introduced as a time-based mapping approach and quantifies lead time but lacks detail on specific loss impacts. Project Time Deployment (PTD) integrates MCT and Manufacturing Cost Deployment (MCD) for better loss management. [9]

During construction, delays may frequently happen and such situations are always reported and stored using different documents. To resolve disputes, companies depend on precise delay analysis. There are difficulties with the current methods because they do not recognize when there are multiple delays. Delay analysis method selection is decided by how much information is accessible. A good method should recognize different types of delays, including those found in effect-based delay analysis method (EDAM). The other main category of Windows delay analysis methods is forward analysis which consists of traditional windows analysis (TWA), modified windows analysis (MWA), along with other variations.[10]

To identify & find the illustrative cases that discuss all types of delays since court cases often use basic and brief information and arbitration cases are usually kept private. A protocol should be set up for gathering these cases as it is necessary for further progress and evaluation of the delay analysis methods which include windows analysis methods.[10]

Scientists analyze risks by assigning them to different categories to make analysis easier to follow. ICRAM lists three important categories of construction risks: risks at the macro level, at the market level and at the project level. Operational, political, financial, technological and legal are included among the categories of risks. There are also authors who divide project management based on the phases and who is involved in the project. Risks may be classified into factors related to cost, time, quality, the environment and safety. [11]

Risk categories in a PERT-based model for time-related project risk management are split by whether the risk can be eliminated. It works to remove risks in the best way possible, staying under budget and within the allowed time span. Risk management is very important in construction to keep delays and losses to a minimum.[11]

Microsoft Project is widely used for managing projects. In project scheduling the precedence diagram is employed for project modelling. A linear programming model helps handle scheduling projects that face time versus cost issues. Microsoft Project is integrated with linear programming for handling scheduling problems.[12]

Precedence relationships are looked at to determine if any activities need to be extended in order to reduce the total time the project takes. The change in the project schedule can be seen in the chart and reviewing both schedules helps spot differences in activity duration. When projects are shortened, what were originally non-critical activities may become critical. Changes in the plan come when project duration is reduced. Also the effect of how marginal costs change with alterations in activity durations can be identified.[12]

76% of those surveyed contractors and consultants reported that said time was extended on their projects between 10% and 30%. Delays often happen because owners want to Change orders. [13]Both owners and consultants see issues with contractors as major causes of delays. 73 causes of delays in construction projects were identified by using questionnaires with statistical techniques and it was found that 70% of such projects suffer from overruns.[13]

Safety management systems are essential for controlling risks through assessments in High-risk industries, like Oil and Gas, have critical safety processes. [14]The Permit-To- Work (PTW) is a formal tool for managing hazardous tasks which communicates among site managers, supervisors, and workers. Resilience engineering highlights the gap between planned and actual work exhibit as higher probability of error in PTW tasks. Functional

Resonance Analysis Method (FRAM) analyze system resilience through PTW process ie differences between Work-As-Imagined (WAI) and Work- As-Done (WAD).[14]

In CPM, the main objectives can be setting the project duration to a minimal for fixed resources, setting the total resource usage to the least to finish the project at a target time and drawing up the time/resource profile that is most efficient across feasible project durations. [15] DTCTP discrete time/cost trade-off problem can benefit from using the methodology of Series and parallel optimizations for reducible projects as well as methods of Reduction plan construction. Project if irreducible, another choice is fixing how resources are assigned.[15]

The schedule compression techniques is used to analyse the delay in construction projects. mixed-integer linear programming (MILP) for scheduling improves time planning effectiveness and compresses schedules through resource allocation in construction projects. [16] The linear programming method supports schedule compression techniques and increasing flexibility in resource allocation for construction project. For multiple process modes the method minimises project duration, rates/prices in tender and demand of capital involved which maximize present value of project.[16]

The fuzzy multi-mode resource-constrained project scheduling problems focus on uncertainty in project activity durations for which solutions suggested by genetic algorithm-based hybrid method.[17]The model aims to minimize total project duration while adhering to constraints of precedence relationships and resource capacity utilization The Resource-constrained project scheduling problems (RCPSP) focuses on uncertainty in project activity durations.[17]

Optimization for minimum maximum delay time in construction project scheduling is handled by using the chance-constrained Programming approach. The model addresses the fact that construction projects are not certain.[18] GAMS (General Algebraic Modelling System) is a software that uses mathematical methods to solve the problems of designing networks, allocating resources and managing the supply chain. It is meant to decrease the longest period a task might take in a project. Target function covers project duration and looks to maximize activities by Crashing which could endanger the project's quality and safety standards.[18]

Because of the current trend toward personalized goods and the changing business sector, resource planning and scheduling more projects become challenging. To get the highest profit, the Raccoon Family Optimization (RFO) algorithm applies eager search and edited genetic operations that focus on early completion bonuses, expenses for mistakes and the costs of resources.[19] Precedence and mode feasibility check & repair procedures (PMFCRP) are introduced to ensure that solutions meet precedence and resource constraints. RFO algorithm works well for organizing and planning more than one manufacturing project when resources are limited [19]

To deal with challenges like not having enough resources and creating recovery plans, RCPSP Resource Constrained Project Scheduling Problem is used to maximize floating resources that can handle future difficulties. By using a multi-method evolutionary algorithm, the suggested approach schedules reactively to enhance flexibility and offer better solutions for problems, along with practical benefits, because it cuts both the modified project schedule (overall length) and the recovery costs after disruption. [20] Indeed, the E-HA Hybrid Evolutionary Algorithm is created from joining two multi-operator evolutionary algorithms (mo-EAs) called mo-GA (genetic algorithm) and mo- DE(differential evolution).. They focus on two groups of populations to make use of their positive traits and avoid their negative ones.[20]

Resource-Constrained Project Scheduling Problem (RCPSP) evolutionary algorithm connected to three heuristics such as earliest start time, neighborhood swapping, and ways to improve the schedule is used to solve the Resource- Constrained Project Scheduling Problem. [21]The influence of the size of a problem, the size of the population, maximum fitness assessments, and local searches is considered. A bigger instance size means that the algorithm spends more computational time, but finishes faster than COA Coati Optimization Algorithm. Finding the right number of people improves the outcome of the decision and prevents wasting resources. From what the Friedman and Wilcoxon tests reveal, it becomes clear that the algorithm serves a major purpose. There was only a little relationship between changes in population and the outcome.[21]

For optimization the mixed-integer linear programming approach (MILP) is used for schedule crashing by moving workers from non-essential tasks to needed tasks, they use more resources to support better scheduling, and adopt schedule compression techniques along with getting subcontractors to handle delay issues. [22]By using the method, the time was reduced by 7% without calling on any additional resources. The cost of projects rose by 40% even though subcontractors made it possible to reduce them by 27.7%. The strategy helps teams manage rescheduling of pending projects.[22]

The construction industry is less safe than others, safety is now one of the major factors affecting success. To help decide on the best time, cost, quality and safety for a road building project, integer linear programming is applied to the related decision-CPM network.[23] Safety is now understood to be a very important objective that is also sometimes forgotten in project management. Resource allocation and decisions in construction projects are improved with the help of integer linear programming. It illustrates how important it is for decisions about planning and scheduling to suit the needs of a project.[23]

CCPSP Critical chain project scheduling problem method, can deal with delays that may happen in a project schedule due to conflicts between resources or uncertainties about availability. It helps to make a schedule with minimum duration and maximum robustness in project scheduling.[24] It combines the CCM with GERT, using it on 480 examples. GERT chooses its critical chain by statistical analysis generating simulation results because it makes it possible to handle the changes in a project and deal with any uncertainty in the schedule. The Garrett network (GERT) presents the remanufacturing process that re- evaluates how waste products could be used or recycled. The use of this algorithm helps improve how the critical chain is found and the solutions suggested.[24]

The layout of natural gas pipelines and their construction projects is linear. This term explains that we can adapt the beginning times and pacing of tasks. Two-stage optimization models that help improve duration as well as reduce cost. [25]Linear scheduling method (LSM) suggests a new way to level resources for linear projects with an extra type of float flexibility for optimizing leveling. The first way to float allows limited flexibility; the second supports some disconnection; the third type gives enhanced space-time flexibility without violating constraints. Resource limitations do not stop LSM from being applied to multiple and similar construction activities.[25]

III. Research Methodology-

The Descriptive/statistical research is used to explain characteristic features of population under study this research is based on reflecting thinking discuss objective and assumptions. It tells answers to question such as what, who, when, where how regarding a phenomenal situation and it is generally quantitative. It is based on conducting a survey about the population and its characteristic.

A. Primary Data-

The primary data collected through interview questionnaire, the data is collected for a specific purpose from the organization for drawing the conclusions and interpretation. The hypothesis will be established for studying the CPM/PERT satisfaction level in the employees/managers. The interpretations of hypothesis will based on statistical analysis P value/F value approach.

B. Secondary Data –The secondary data of a project on Fire protection system in various oil & gas installations, involves construction activities of Civil Infrastructure & process installation. The calculation as per applicable OISD recommendations is carried out & then scheduling represented on Gantt chart. Analysis by PERT & CPM techniques concludes cost saving measures. The project timeliness in evaluated and effect of each activity may change the output of project in terms of finance & durations.

C. Research instrument and data gathering

The tools is used to study through structured questionnaire with five point Likert type scales through which responders specify their level of agreement or particular statement in five point grade scale such as strongly disagree ,disagree, neither agree nor disagree ,agree, strongly agree.

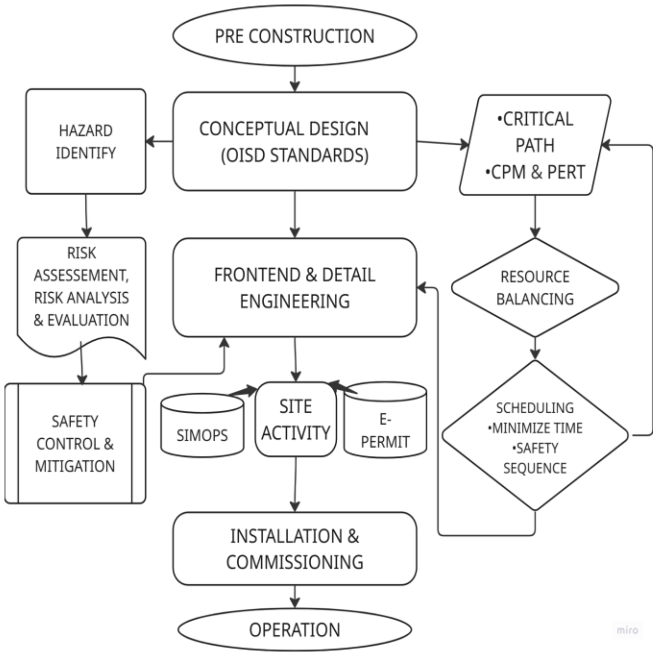

Fig 1. Stages of Construction Projects (Oil & Gas) with Risk mitigation.

D. Hypothesis –

Null Hypothesis (Ho) - There will be NO significant relationship between use of CPM/PERT Project management tools in optimization and satisfaction level of Manager for safe execution of project. Alternate Hypothesis (Ha)- It ascertains for the significant relationship between use of CPM/PERT Project management tools in optimization and satisfaction level of Manager for safe execution of project.

E. Mathematical Equation-

Liberatore and Pollack-Johnson's equation helps assess the link between quality, time, and cost in project activities so that responsible decisions are taken to reach the desired quality goals using the given budget and schedule. It tries to link quality concerns with analysis of time versus cost using linear equations.[26]

Quality Q(t,c) of a job as a function of time t and cost c. The equation is typically expressed as:

$$Q(t,c)=K\cdot e^{-((t-\mu t/\sigma t)2+(c-\mu c/\sigma c)2)}$$

Q(t,c): Quality level achieved for a job given time t and cost c.

K: A scaling constant representing the maximum achievable quality.

μt: The mean or target time for the job.

σt: The standard deviation or tolerance around the target time.

μc: The mean or target cost for the job.

σc: The standard deviation or tolerance around the target cost.

e: The base of natural logarithms (Euler's number). Equation for Safety as a function of time (t) and cost (c):

$$\text{Safety}\ (t, c) = S \cdot e^{-((t-\mu t/\ \sigma t)2 + (c-\mu c/\ \sigma c)2)}$$

S: Maximum safety achievable at the optimal point. μt μc: Optimal (mean) time and cost for safety.

σt, σtc: Standard deviations for time and cost, indicating how much safety degrades moving away from the optimal values.

The interpretation of Peak Safety depicts Safety is highest when both time and cost are at their optimal values (t = μt c

= μc).Degradation of Safety: Any deviation either increasing or decreasing time or cost causes safety to decrease, following a bell-shaped (Gaussian) curve. Trade-offs: Reducing time or cost below optimal ie Safety drops and Increasing time

IV. Safety Standards For Oil & Gas Installations

The safety standard for Oil & gas installation in onshore is formulated and reviewed by OISD, Oil India Safety Directorate, MOPNG. The standards are applicable during design installation and commissioning of projects. In reference to OISD 116, OISD 117 & OISD 189.

V. Results And Discussion-

DESCRIPTIVE STATISTICS - DATA OF RESPONDENTS

Table 1. Anova: Two-Factor Without Replication

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	12.48	9	1.38	3.86	0.00168	2.152
Columns	8.68	4	2.17	6.046	0.00079	2.633
Error	12.92	36	0.358			
Total	34.08	49				

Table 2. Hypothesis Data from Excel & Descriptive Statistics:

CRONBACH'S ALPHA	0.74119	ACCEPTABLE
Formulae= 1-(ErrorMS/ Rows MS)		RELIABLE

Inferences drawn from table that P VALUE<0.05 &F Calculated > F Critical then we must REJECT NULL HYPOTHESIS and accept Alternate hypothesis.

Ha- There is a significant relationship between use of CPM/PERT Project management tools in optimization and satisfaction level of Project Manager for safe execution. of project.

Hence there is significant relationship & impact of CPM/PERT Project Management tools for optimizing the project cost & time for safe execution. of project.

By CRONBACH'S ALPHA = 74.12% which interprets data consistency, acceptability & reliability.

VI. Conclusion

The approach for cost optimization & resource levelling can provide the Critical path for completion of projects considering the safety aspects. The compliance and adherence through Safety standard during planning & execution stage minimize the unplanned event of incident resulting to accident and loss of property. The Financial gains of the company in terms of prevention of Indirect losses is of utmost importance and crucial to prevail in competitive markets.

The future research area may include the inclusion of latest technologies of Artificial intelligence & Machine learning in each stage of projects which may alert the project managers for prevailing hazards & risks involved during pre-startup of projects.

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