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Pert and Petri Network Modeling For Opencast Coal Mine

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Abstract: ***Among the four prime industries i.e. agriculture, fisheries, forestry and mining, Mining is the oldest industry in the world. The primitive society relied nearly on mined produce that is reflected aptly through nomenclature such as Stone Age, Copper Age, Bronze Age and Iron Age. These nomenclatures rightly capture the ethos of the time that shows increasing complexity of people's society's relationship with mining produce and use of metals. Our remote ancestors did practice mining on hard rock. Mining remained with their common occupation to earn livelihood and meet their needs. Since they had meager requirement of fuels; their major need of fuel was met mostly from dense forests on the earth. As the time passed, they required to meet ever increasing standards of living. As a result, demand of fuel was felt as extremely necessary for the existence of mankind and it kept on growing. In order to meet ever increasing demand, mining of coal took a shape in one way or the other. Mining needs strategic, tactical and operational decisions, specifically, in this context, of how to design mines and extract the ore most profitably.***

Operations research (OR) has played an important role in the analysis and decision making of natural resources i.e. agriculture, fisheries, forestry and mining, in the last 40 years. At some level, these four application areas are quite distinct. The time horizons of growth and extraction (or harvesting) vary from months to a year for fisheries and agriculture, to almost a century for some tree species. Mining is non-renewable and as such, is associated with a different type of natural resources. Mining activity will run for a few years to centuries. Correspondingly, there are natural differences related to the form of managing the production in each application.

OR techniques in the Indian coal mining industry are relatively new and just at an infant stage. OR have been applied to handle problems in mining elaborating on mathematical techniques, presenting challenges and describing successful applications. The application of Petri Nets gets acceptance among mining community and it is now taking long strides, to incorporate automation in the operational sectors of mining industries.

This paper is organized application of PERT & PETRI Network modeling for opencast coal mine specifically in planning, related environmental concerns, decision-making strategies in respect of mining activities

Keywords: Operation Research, PERT, PETRI Network, EMP, CPM, PDM

I. INTRODUCTION

Out of the sources provided by Nature for producing wealth as fruits of man's endeavours like parenthood, regeneration, hunting and fishing, forestry, agriculture, husbandry and mining. Mining is a source to obtain minerals like metals, oil, coal etc. Oil and coal are major raw materials to serve as fuel in the present time. Rapid growth of oil industry and invention and subsequent innovations of internal combustion (IC) engines and emergence of electricity as an optional power brought about a decline in direct use of coal as energy source. However, the subsequent worldwide energy panic of the 1970's that resulted from oil embargo restored back coal to its prominent position in the world scenario. Dwindling position of oil reserves across the world is another potent reason to raise coal utilization to prime concern. Since coal continues to enjoy advantage over other

energy sources, and since reserves of coal are much ample and assured the world wide in comparison to rival energy sources, coal utilization comes to the forefront.

India being an oil-deficient country makes a clear choice to boost up coal production and to rely more on it as energy source. Since industrial revolution captured the nerve of the world in the late 19th and 20th centuries, energy sectors acquired prime concern with a view to fulfilling energy requirements for survival and efficient functioning of industries. As a result, the need of coal production was felt more acutely. It comes to almost 60% of the energy resources in the Indian scenario. Out of the four major fuel sources in India – oil, natural gas, coal, and uranium – coal has the largest domestic reserve base and claims the largest share in India's energy production.

Mining activity is exploiting naturally occurring, non-renewable resources within the earth. Mining differentiates itself from other common natural resource areas, e.g., fisheries, agriculture and forestry, primarily that in mining the minerals are non-renewable. Once a deposit has been fully exploited, the site is permanently closed. Furthermore, mankind has no control over where these resources occur. And once an ore body has been identified and analyzed via geological sampling, the reserves are proven and do not diminish (or flourish) based on external environmental factors such as floods or benevolent weather. In fact, human intervention is primarily responsible for the grade and type of ore recovered relative to the projections of the nature of an ore body. Nonetheless, as with any natural resource, it must be exploited subject to certain geometrical (precedence) restrictions, limits on the rate at which the resource can be processed and the quality of resource extracted. Goals in extracting the resource are similar to those regarding the extraction of other natural resources:

(i) Maximize net present value,

(ii) Minimize the deviation between the amount of extracted resource and a contractually specified amount,

(iii) Minimize impact to the environment,

(iv) Maximize production or throughput and/or

(v) Maximize operational flexibility with a view to minimizing risk.

The stages of mine development consist of prospecting and exploring an ore body of interest to determine whether ore extraction might be economically viable. Economic, geological and statistical tools are often used at this stage to predict the quality of the ore body using sampling techniques and to estimate the value of the ore body using economic techniques. If an ore body is deemed economically viable, it can be profitably developed and exploited. It is in these stages that operations research tools are most commonly used to design the ore body and subsequently to extract ore. Finally, the exploited area must be returned to its original, or at least to an environmentally acceptable, state.

II. Population & Consumption of Minerals, Ores

After China, India has the second largest population in the world, with 1,224 million people (2010). It has the highest population growth rate amongst the BRIC countries. Projections show that until 2050 this growth rate will still be positive in contrast to numerous Western countries with already negative current growth rates. By 2025, India will become the most populated country in the world.

Figure 1: Growth of India's population (actual and projected) compared to China and Europe

Figure 2: Absolute consumption of materials in India, 1980–2009

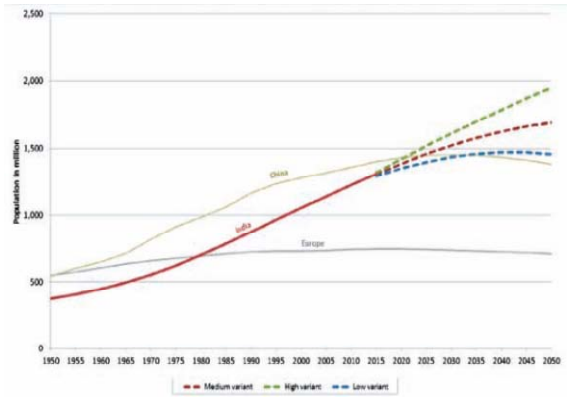

Figure-1

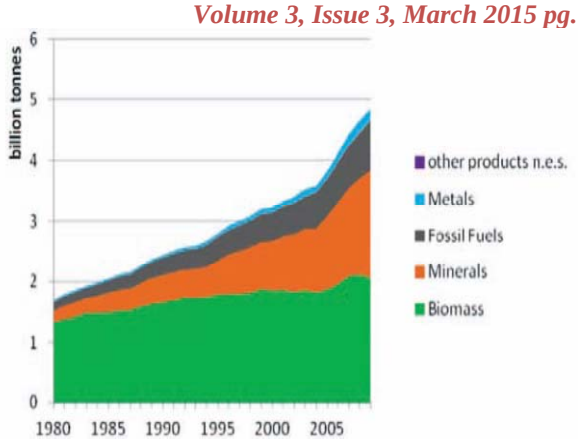

Figure- 2

This increase in population would lead to a sharp rise in absolute consumption levels, and hence the need for improving resource efficiency will assume great importance. Due to the high saving potential in populous countries, and the opportunity of changing the development path towards a resource-efficient economy, addressing resource efficiency in India makes perfect sense.

III. Exploitation of Minerals /Ores

Minerals/ores including coal are developed and exploited either on the surface or underground. Surface mining is the more common and straightforward method. Typically, open pit models maximize net present value subject to restrictions on the way in which ore can be extracted, and to resource, e.g., production and capacity, constraints. Underground extraction is more complicated, not only because there are a variety of underground methods that are used depending on the nature of the ore body and surrounding waste rock but also because more operational restrictions are usually involved, and because these operations tend to be very specific to a particular mine.

Operations Research is the science of rational decision-making and the study, design and integration of complex situations and systems with the goal of predicting system behavior and improving or optimizing system performance. Operations research modeling applied to mining applications dates back to the 1960s. Currently, operations research models for strategic, tactical and operational levels of planning within the development and exploitation phases have been constructed and implemented.

IV. PERT & PETRI Net Modeling

The present era of open ended global markets put the survival of mining business unit at stake due to severe economical conditions. The cost of mining has to be minimized. It requires a review of the present practices and adoption of innovative strategies. In a fast moving mine production scenario, target based planning and scheduling becomes a key word to arrive at a position to achieve the desired output. Scheduling at opencast coal mine project requires: hierarchical decomposition of projects activities as well as risk and uncertainty in the activity time and cost estimates and modeling of dynamically allocated resources. Traditional network techniques that are currently used at the mining industry provide limited modeling versatility and are bit ineffective in modeling a dynamic and stochastic system. The PERT (Programme Evaluation and Review Technique) charts have long been used in the planning and scheduling of large projects. A PERT chart is a graphical representation of relationships among various activities which make up a large project. A project consists of a number of activities which have to be completed before start of other activities. In addition, time associated with each activity indicates the amount of time it will take. Activities are represented graphically by a node; arcs are used to connect activity nodes to show precedence requirements.

The Petri nets show a similar type of scheduling constraints as the PERT chart does. The PERT chart can be easily converted to the Petri net. Each activity in the PERT chart is represented by a place, while the precedence constraints are represented by transitions. Planning, scheduling and control of the functions, operations and resources of a mining project are among the most challenging tasks faced by the professional mine manager. The outcome of a particular mine facility is a multi-

phase task that begins with conceptual planning and continues through detailed design, implementation and regular follow-up phases. The successful completion of the mine facility requires numerous inputs and efforts.

The first requirement for the mining is to acquire land. The procedure to acquire especially forest land is most cumbersome in India. For the purpose, EMP (Environmental Management Plan) needs to be formulated & approved and other formalities are to be completed. An EMP is a site-specific plan developed to ensure that all necessary measures are identified and implemented in order to protect the environment and comply with environmental legislation. In order to succeed in such endeavours, it is employ techniques like planning, scheduling, and co-ordination of important decisions, determining milestones, ensuring flow of resources, and other required inputs. It is important to prepare some form of representation of the designed facility to allow such a planning, scheduling and co-ordination effort to be effective. A common form of representation used at the mining industry is a bar chart or other network based methods such as Critical Path Method (CPM), Program Evaluation and Review Techniques (PERT) and Precedence Diagramming Method (PDM). Short-comings of these methods are numerous and they are reviewed in many research work. The major problem that is highlighted by them is that network techniques are adopted from current practices at the aerospace and manufacturing industries when it is done in disregard to the nature of the mining projects. Following major characteristics of mining projects exert adverse effect by reducing effectiveness of the network based techniques.

They include the following:

1. The task of executing a facility can be decomposed into sub-tasks requiring services of specialists like land officer, civil engineer, electrical and mechanical engineers, excavation engineer, surveyor, environment officer, finance officer, personnel officer, construction engineers, general contractors and specialist contractors, etc. These specialists normally belong to different disciplines that are inter-related. A flow of information and the resultant decision making are as such complicated. They render the tasks of planning and scheduling as more complex.
2. Mining projects are operated in a dynamic environment. They are characterized by stochastic phenomenon such as land acquisition constraints, labour productivity and skill fluctuations and variation in geo-mining characteristics.

In this light, the Graphical Evaluation and Review Technique (GERT) is thought to be reviewed. The reason is its development which extends the modeling capabilities of CPM and PERT. These experiments lead to a use of simulation in the project planning and scheduling. The following paragraph provides a summary of important research conducted in this area. A technique called Probabilistic Network Evaluation Technique (PNET) applies probability theory to reduce number of possible critical paths and evaluates the expected project duration based on representation paths in the network. This research suggests a shift in the scheduling paradigms by adopting the Petri nets. In an opencast mine, the Petri nets is, in fact, serve as the backbone of scheduling system

Planning process is divided into three broad segments:

i) **Long Term Planning**: This segment assesses an overall profitability of a proposed mining operation. Here mines are designed with sufficient detail to provide necessary information as to whether a deposit is of value to consider a more detailed analysis. The time frame may be extended up to the life span of the mine.

ii) **Medium Term Planning**: The time frame for this segment may extend from one month up-to two years. It is here that the conceptual pit designs are converted into detailed realistic designs. These designs may be given to short range planners.

iii) **Short Range Planning**: Here, day to day planning process is involved in this segment. The time frame may typically range from one day to one or two months depending on a type of operation and tonnage of mineral to be extracted.

In any mining operation, there is considerable overlapping in the above segments. One may merge into another rather than leaving any clear perception of what is universally acceptable. Each mining department nominates a specific time frame to be assigned to each planning process. These time frames of reference may change depending upon the direction of the company and other economic or political influences. Most recent works in the field of mine planning and production scheduling focus either on computerization of traditional methods or on development of sophisticated mathematical optimization models. It is clear to all concerned that the optimizers need to be more practical, and the traditional approach needs to be more optimal. The program reviewed in the present research opens a middle ground to strike a balance between these two approaches. The traditional and optimization approaches that are in current use presume that each one of them finds difficulty in identifying with the other. This may be time especially when we consider the difficulty of understanding the optimization models that one who is not trained in operations research may face. This research seeks to explore a position that the proper role of the operations research renders it as not only a useful and advantageous approach, but also renders it practical, understandable and easy to implement as well.

Network analysis in project planning (CPM & PERT)

A project in the context means one-time operation which has a well defined end-point. In case of an opencast mine, the end point is a date when a targeted capacity is achieved, that is production of coal is obtained as per a planned schedule.

The Network planning consists of arranging the precedence and sequence of project tasks appropriately to provide a road map of execution of the project. It starts with the construction of a diagram, known as 'network diagram'. The diagram reflects the interdependencies and time requirements of the individual tasks that constitute the project. The sequence, interdependencies and time requirements are analyzed further to obtain what may be termed as "planned" duration of the project. Two most popular forms of this technique that are currently used in many scheduling situations are (1) the Critical Path Methods and (2) Program Evaluation and Review Techniques. Its objective was to aid in the scheduling of routine plant overhaul maintenance and construction work. This method differentiates between planning and scheduling. Planning refers to determination of activities that must be accomplished and the order in which such activities should be performed to achieve an objective of a project. Scheduling refers to the introduction of time into a plan thereby creating a time table for various activities to be performed. CPM operates on an assumption that there is a precise known time that each activity in the project will take place. The PERT allows a manager to calculate the expected total time that the entire project would take to complete. It happens at the stage of formulation and planning of a project. At the same time, it highlights critical or bottleneck activities that are likely to occur in the project. It is in this light that a manager may either allocate more resources or keep a careful watch on such activities as the project progresses. In the PERT chart we usually assume that the time to perform each activity is uncertain and as such three time estimates namely, the optimistic, the pessimistic and the most likely are used. The PERT incorporates statistical analysis in determining the time estimates and enables determination of probabilities concerning the time by which an activity as well as the entire project would be completed. The PERT is a control device. It assists the management in controlling a project once it starts working. It calls attention as a result of constant review to such delays in activities. It might further cause a delay in the completion time of a project. This network is a graphic representation of various operations of a project. It is composed of activities and events that must be accomplished in order to reach the end objectives of the project. It shows a planning sequence of the accomplishments, their dependence and interrelationships.

The activities can be classified into the following three categories:

1) **Predecessor activity** is an activity which has to be completed before one or more other activities would start.

2) **Successor activity** is an activity may start immediately after one or more of other activities.

3) **Dummy activity** is an activity that does not consume either any resource or time. A dummy activity is depicted with a dotted line in the network diagram. A dummy activity in a net-work is added only to represent a given precedence relationships among activities of a project. It is needed when –

a) Two or more parallel activities in a project have same head and tail events.

b) Two or more activities have some (but not all) of their immediate predecessor activities in common.

Petri Net modeling technique

Petri net modeling technique can be of utmost help to sort out the difficulties and to resolve the complex mining problems. Petri nets are multi-focal tools. Petri nets, as graphical and mathematical tools, provide a uniform environment for modeling, formal analysis and design of discrete even systems. Further, the Petri nets as graphical tools provide a powerful communication medium between the user, typically requirements engineer and the customer. Complex requirements specifications, instead of using ambiguous textual descriptions or mathematical notations difficult to understand by the customer, can be represented graphically using the Petri nets. As mathematical tool, the Petri net model can be described by a set of linear algebraic equations, or other mathematical models reflecting behaviour of a system. The ability of the Petri nets to verify the model formally is especially important for real time safety critical systems such as air-traffic control systems, rail traffic control systems, nuclear reactor control systems, etc. Petri nets are extensively used currently to model and analysis of communication networks, manufacturing systems, software systems, performance evaluation, etc.

Petri net is graph-based mathematical model. These models are promising tools for describing and studying manufacturing systems. Moreover, the Petri nets are very much suitable to describe the tradeoff between flexibility requirements and control policies. They help to improve efficiencies. Usually, this is a major issue to bother open cast mining systems.

The benefits of applying Petri nets to mining system for modeling are as follows:

1. The Petri nets can easily represent concurrent operations.
2. The Petri nets can represent machine breakdowns, tool failures, and detect occurrences with inhibitor arcs.
3. The Petri nets can model irregular and frequent part-type changes with mutual exclusion.
4. System modeling can be simplified by dividing the Petri net into several modules. By using these, a study of complex systems may become more convenient.

The Petri nets works on the following twelve criteria.

1. The ability to represent lead time.
2. The ability to represent a schedule.
3. The ability to represent a logical relationship and parallel asynchronous process.
4. The ability to represent an overlapping and/or a waiting activity.
5. The ability to represent a choice of alternative activities.
6. The ability to represent a resource and its allocation.
7. The ability to represent a hierarchical modeling.
8. The ability to represent a modification of the network.
9. The ability to represent an actual state of system.
10. The communicability between man and graphic model.

11. The simulation capacity.

12. The readability on a graphic display.

Other graphic methods such as GANTT charts, PERT technique, UCLA graph, control graph and GRAI Net, are unable to satisfy these twelve criteria simultaneously. The criteria may lead to a study of the Petri net based graphical representation. A marked Petri net may describe a model of any discrete system where: - Net describes the structure of a system, marking describes the state of a system, evolution of the marking describes the functioning of a system.

Modeling activities in an opencast project by a PERT network

The success of any large scale project is much dependent upon proper planning, scheduling and controlling of various phases of a project. The PERT network is used on large scale projects as a management tool. It expedites and controls the utilization of the resources i.e. personnel, materials, facilities and time so that the critical areas in a project may be pinpointed. Accordingly, necessary corrective action can be taken to meet the scheduled completion date. The PERT chart is a graphical representation of the relationships between various activities. The activities are represented graphically by arrows and events by nodes. The longest path through the PERT network is referred to as the critical path. It is a path that is followed to obtain the TE (earliest expected completion time of the event) value for the final event. Timing interpretation can be added to activities for the purpose of evaluating the completion time of a project.

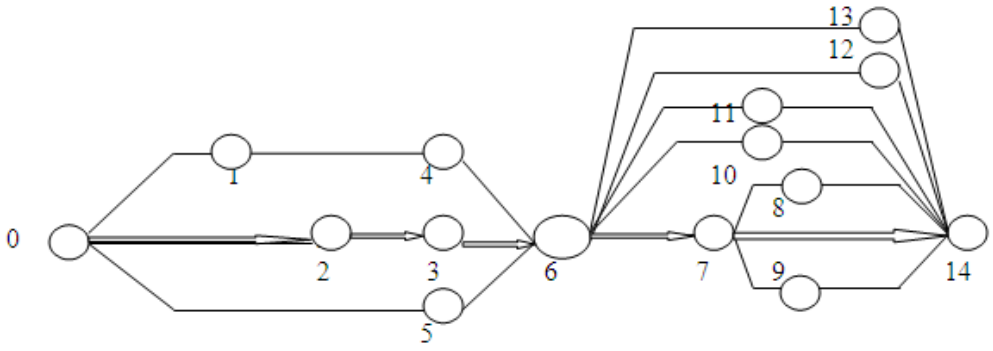

FIGURE-1- PERT network of an open cast coal mine for expansion

Table 1 Activity schedule and duration of PERT network

ACTIVITY	PARTULARS	MONTHS
1. 0-1	PR Approval By the Company	3
2. 0-2	Stage-I Forestry Clearance	6
3. 0-5	Action for HEMM Procurement & Manpower Deployment for P1	9
4. 1-4	Land Acquisition, Phase-I	6
5. 2-3	EAC & Stage-II Forestry Clearance	2
6. 3-6	MoEF Clearance	2
7. 6-7	Coal Production and OB removal in P1	9
8. 6-11	Addl. Workshop Complex Construction	14
9. 6-10	Addl. Project Substation Construction	14
10. 6-12	Additional Haul Road & Water Supply	18
11. 6-13	Addl. Land Acquisition	19
12. 7-8	HEMM Procurement & Commissioning For P2	3
13. 7-9	Manpower Deployment for P2	
14. 14	Coal production and OB removal in P2	12

The present study reviews the PERT network in the context of an open cast coal mine that produces 2.0 Mt of coal per annum. It has to be enhanced further to 3.5 Mt per annum. The matter is still under considerations. The incremental production of 1.5 Mt is divided into 1.25 Mt and 0.25Mt.for first year and second year respectively. It may be for the implementation of the expansion project. The PERT chart is prepared from the date when the project report (PR) is submitted till an achievement of targeted capacity of. 3.5 Mt/annum. Hierarchical decomposition of different tasks (activities) is carried out to identify the constraints. This may be encountered in the course of implementation of project activities. The activities like PR approval by the company, land acquisition, forestry clearance. MOEF clearance, HEMM procurement, manpower development, additional haul road construction, water supply, substation construction, workshop complex etc are projected in the PERT network with their earliest completion time & latest completion time. The critical path (0-2-3-6-7-14) is also marked in the network. (Figure 1).

Conversion of PERT chart into equivalent Petri net model

The Petri Nets show the same type of scheduling constraints as the PERT chart does. We can easily convert a PERT network to a Petri Net model. Each activity and event on the PERT chart is represented as transition and place respectively in case of the Petri net model. The Petri Net is an excellent vehicle to represent the concurrency and precedence constraints of the PERT chart. In modeling the PERT chart with the Petri Net, activities that are represented by transitions and places are reserved to model multiple resources of limited amounts.

This simple PERT network (Figure-1) is converted to an equivalent Petri net (Figure 2)

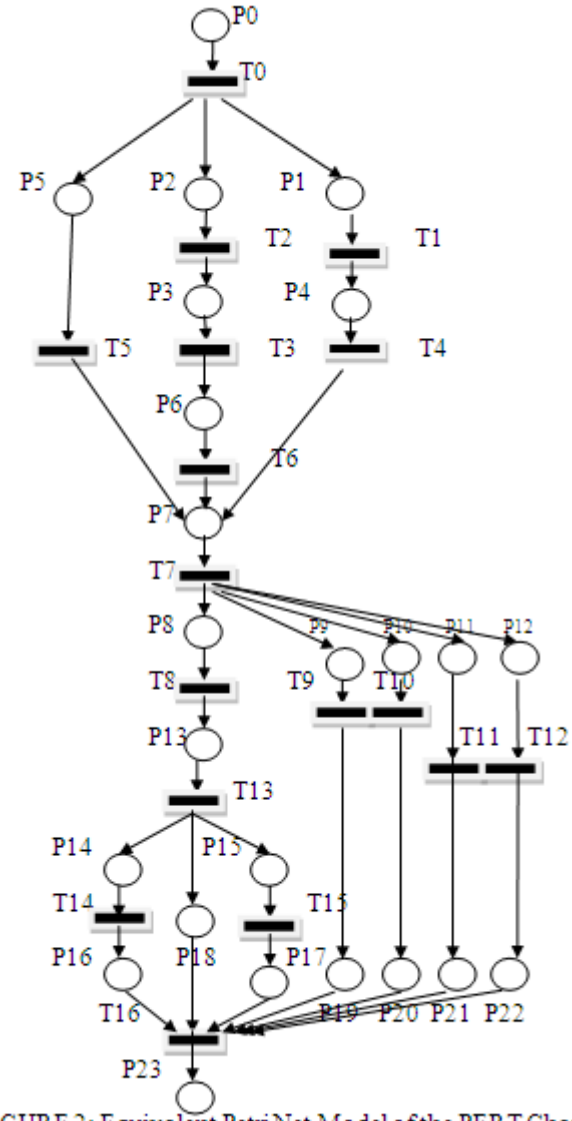

FIGURE 2: Equivalent Petri Net Model of the PERT Chart

The dummy transitions are added as per the need to cater to the requirements of timely completion of the activities. Figure 2

Table 2– Description of scheduling operation and its interpretation

Place		Transition	
P0	PR submission starts	T0	PR submission is in progress
P1	PR submission is complete and PR approval process commences	T1	PR approval process is in progress
P2	St.I forest clearance commences	T2	St.I forest clearance is in progress
P3	St.I forest clearance is complete and EAC St.II forest clearance starts	T3	EAC St.II forest clearance is in progress
P4	PR approved is completed and Land acquisition Ph.I is commenced	T4	Land acquisition (Ph-I) is in progress
P5	Action for HEMM procurement and manpower deployment for P1 commences	T5	HEMM procurement and manpower deployment for P1 is in progress
P6	EAC ST.II clearance is complete MoEF clearance is commenced	T6	MoEF clearance is in progress
P7	MoEF clearance is complete and Land acquisition (Ph-I) is complete	T7	Action for infrastructure development is contemplated
P8	Coal production and OB removal in P1 is commenced	T8	Coal production and OB removal in P1 is in progress
P9	Addl. workshop complex construction work begins	T9	Addl. complex construction work is in progress
P10	Addl. project substation construction begins	T10	Addl. project substation construction is in progress
P11	Addl. haul road and water supply work begins	T11	Addl. haul road and water supply work is in progress
P12	Addl. land acquisition is commenced	T12	Add land acquisition is in progress
P13	Coal production and OB removal for P1 is complete	T13	Coal production and OB removal for P2 is contemplated.
P14	HEMM procurement and commissioning for P2 is commenced	T14	HEMM procurement and commissioning for P2 is in progress
P15	Manpower deployment for P2 is commenced	T15	Manpower on deployment for P2 is in progress
P16	HEMM procurement for P2 is complete		
P17	Manpower deployment for P2 is complete		
P18	Coal production and OB removal for P2 begins	T16	Coal production and OB removal for P2 is in progress
P19	Addl. workshop complex construction is complete		
P20	Addl. project substation construction is complete		
P21	Addl. haul road and water supply work is complete		
P22	Addl. land acquisition work is complete		

The Petri Nets are more powerful models as compared to the PERT/CPM charts. Following reasons are given for it:

1. The repeated performance of activities, if necessary, can be modeled by the Petri Net.
2. Required resources per activity appear explicitly as tokens in the representation.
3. Non-deterministic aspects can be dealt with. For example: the order in which a particular resource performs some tasks may not be totally specified.

The Petri Net based scheduling of mining projects that are reviewed as a simple and effective method. It may provide mine managers an assistance to develop/work out realistic time and cost estimates for complex mining projects. A practical case study is analyzed. An attempt is made to bring some changes in the usual and traditional system of PERT network incorporation in the Project Report. A thorough study and analysis of the Petri net model is necessary for validation of data and results. There is enough scope of research in the field of application of the Petri net in the mining. Various advantages such as of Petri net network are as under: -

1. A hierarchical and modular decomposition of complex mining projects can reduce the complexity of the project network.
2. Cyclic and probabilistic arcs can be used to model uncertainty and risk,

3. Uncertainty in the time and cost estimates can be modeled by using appropriate statistical distribution.

In order to model the shared resources and the dynamic allocation of resources, colored Petri net can be used by the mine managers to predict resource availability problems.

V. CONCLUSION

The present day market scenario is highly competitive and dynamic. Capital investment of any kind needs to have presumption and production based on efficient engineering as well as financial analysis. It helps to establish profitable proposition. In terms of coal markets, a high demand of coal focuses concerned attention on the coal mining industry. Consequently, a close attention is paid to the aspects of mechanization of the opencast mining. It is, therefore, thought more appropriate to express the productivity in terms of cubic meters of volume of excavation (coal and OB) per man-shift in place of the conventional output in tones per man-shift. As far as the profitability of an opencast mine is concerned, it is important to adopt a broad and preferably long term outlook that may be based on mathematical models. The present study seeks to evolve a method to minimize cost of production right since the stage of planning and designing of opencast mining projects. For the drilling and blasting, an optimal design is needed, while for the loading and transportation, optimal allocation of machines combination is required. Monitoring of various parameters of an opencast mining project may be affected on the basis of network analysis. It is essential to avoid any cost overrun or time overrun. The investigations are carried out on the above aspects keeping in view the maximization of productivity and profitability of opencast mining projects. It may result in significant benefits in the long run provided it is followed up properly. Planning at highly mechanized opencast mines is worked out with an objective of high production of coal and, thus achieving high productivity. With a very high capital cost requirements for mechanized opencast projects, the coal industry can no longer afford to make decisions in respect of strategic as well as tactical planning solely on the basis of experience and subjectivity no matter whatever may be the reasons for mechanization. The management is ever confronted with crucial decisions as to how much amount of capital needs to be spent on each sub-system towards its mechanization and how to achieve a pertinent target. The management has to seek to justify the investments on both on short term and long term grounds. Petri net model is worked out for shovel-dumper allocation. The initial activities of opencast mine operations are normally represented in a PERT network in a Project Report. An attempt is made to convert these initial activities from the usual PERT chart to the Petri net model to allow better analysis and simulation. It helps in effective implementation and monitoring of various activities in time so that the target of a project is achieved in due time without allowing any time overrun or cost overrun to occur. The present research work has basic concern with the applications of Strategic Planning Models and Operations Research Techniques in production planning and optimal resource allocation at opencast mines The Petri net model developed under this study is essentially analytical in nature. It can be applied to develop automation and robotics in the field of opencast mining technology. An application of stochastic Petri net modeling and Operations Research techniques to various mine sub-activities needs to be addressed to find out a suitable method for optimal production of coal and OB at opencast mines.

It is opined that in the present time of globalization and economic liberalization, the mine planning as well as its operations of opencast mining need to be taken up judiciously and objectively. It has to be based on a rate of growth and development at par with the international standards. The techniques and tools of the Strategic Planning Models and Operations Research concepts may be availed, or else, the very survival of the mining industries will be at stake.

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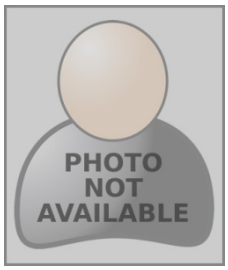
ABBREVIATIONS

IC-Internal Combustion, EMP-Environmental Management Plan, PERT-Programme Evaluation and Review Technique, CPM- Critical Path Method, PDM - Precedence Diagramming Method, GERT- Graphical Evaluation and Review Technique, PNET -Probabilistic Network Evaluation Technique, OB- Overburden

AUTHOR(S) PROFILE



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