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OPERATIONS RESEARCH- AN OVER VIEW AND ITS APPLCATIONS IN MINING ORGANISATIONS IN INDIA

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Abstract

There are many mining organizations in India contributing in economic development. The output is produced involving all functional managements gifted with proven expertise and experience. The enlightened management teams on appreciating the scope and utility of "Operations Research(O.R)" have been utilizing it for decision making on vital issues that interface with different disciplines like; production, marketing etc. O.R is a technique that is multi-disciplinary in nature due to which the organizations have rightly been involving executives from different functions , like production, Finance etc., a **sine- qua- non** for the very success of OR. The mining organizations operate a number of mines with different technologies in rather dispersed geographical locations that possess both inherent advantages as well as nature induced constraints to be dealt with. With limitations of resources and constraints, O.R is successfully utilized to decide questions, such as the "Optimum Annual Production targets" for the various mines utilizing "Linear Programming Method". The other successful O.R applications have been Inventory Management, Queuing theory, Simulation etc. to cite a few. The genesis of O.R in India along with a no.of various applications in Mining organizations are incorporated in this Paper. While the order of the day is Liberalization, Privaitazation and Globalization the paper is concluded with a small message on the possible positive role of O.R for successful functioning of the trinity of Liberalization, Privaitazation and Globalization. ----------

Keywords:

Operation Research;
Mining;
OR applications;
Simulation;
Make or buy decision.

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1. Introduction

The Operations Research(OR) is a widely accepted discipline that deals with the application of advanced analytical methods to help make *better decisions*. This process helps to derive optimal or near-optimal solutions to complex decision-making problems of managements. Gaining an insight into the structures & processes that OR can offer and the practical utility of these techniques in business would be an asset to the management.

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2. Historical background:

Operations Research origins in World War II ushered in by the military services, as urgent need was felt to allocate (scarce) resources in an efficient manner. Great Britain and USA called for large pool of expert mathematicians, statisticians, scientists, engineers; from various disciplines who were ordained to do research on military operation(s). Thus the name and origin of O.R substantiates the adage "Necessity is the mother of invention".

It is gratifying to record that one of the pioneers of O.R in the post-IInd world war was George B Dantzig(Germany)(developed the popular Linear Programming)[2]. The Post-war, international business environment led to Industries and business organisations also start utilizing O.R to solve their constantly emanating complex decision problems.

3. Definitions of Operations Research (O.R)

C. W. Churchman who is considered one of the pioneers of O.R. defined it as the application of scientific methods, techniques and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to problem[1].

More Definitions[2] were offerd by; 1.Philip McCord Morse and George E. Kimball, 2. Russell L.Ackoff and C.West Churchman 3.Saul L Gass 4.O.R.Society, UK. 5. Committee on O.R.Research Council, USA. 6. Daellenbach &George, 1978. 7. Theirauf & Klekamp, 1975. 8. H.A.Taha, 1976.9.S.L.Cook, 1977. 10. F.S.Hiller & G.J.Lieberman, 1980. 11. D.W.Miller & M.K.Star, 1969 & H.M.Wagner etc.

Text books and literature on the O.R provide details on its Meaning, nature, charecteristics and other related scope.

4. Meaning of O.R

Operations research (O.R) means applying scientific and mathematical methods for decision making and problem solving. O.R does not provide decisions but provides quantitative data to the managers. The managers use this data for making decisions.

5. Nature of O.R:

(i) Purposeful Research Approach(ii)Wide Application (iii) Specific OR Process(iv)Practical orientation etc

6. Characteristics of O.R [3]

Three essential characteristics of operations research are;

(i) A systems orientation,

(ii) The use of interdisciplinary teams, and

(iii) The application of scientific method to the conditions under which the research is conducted.

7. Features of O.R [2]:

O.R .displays features such as;

i) Interdisciplinary approach ii) scientific approach iii) Holistic approach & iv) Objective-(solution) oriented approach

Further, O.R Approach to Problem Solving is dealt in 3 Phases.

i) Judgement phase ii) Research Phase & iii) Action Phase (Akin to Principles in Research Methodology Course)

8. Methodology of & Steps in O.R:

(i) Step 1: Defining the Problem
(ii) Step 2: Formulating a Mathematical Model
(iii) Step 3: Solving the Mathematical Model
(iv) Step 4: Validating the Solution
(v) Step 5: Implementing the Solution
(vi) Step 6: Modifying the Model
(vii) Step 7: Establishing Controls over the Solution

9. Popular Techniques of Operations Research:

Important techniques of Operation Research are being described hereunder[5]:

(i) Inventory Control Models:

Operation Research study involves balancing inventory costs against one or more of the following costs: such as; i.Shortage costs ii. Ordering costs iii. Storage costs iv. Interest costs.

This study helps in taking decisions about: i. How much material quantity to purchase. ii. When to order for purchase .iii. Whether to manufacture or to purchase i.e., make and buy decisions.

The most well-known use is in the form of Economic Order Quantity equation for finding economic lot size.

(ii) Waiting Line Models

These models are used for minimising the waiting time and idle time of the concerned stake holding systems together with the costs associated therewith.

(iii) Replacement Models

(iv) Allocation Models

(v) Competitive Strategies

Such type of strategies are adopted where, efficiency of decision of one agency is dependent on the decision of another agency.

(vi) Linear Programming Techniques:

These techniques are used for solving operation problems having many variables subject to certain restrictions.

(vii) Sequencing Models

(viii) Simulation Models:

Simulation is an imitation of reality and mainly it studies behavior (of resources and processes) over time.

(ix) Network Models:

This is an approach to planning, scheduling and controlling complex projects.

Some more applications of operation research in various functional Managements[2]:

(i) Finance & Accounting:

Ares of application: Dividend policies, B.E.Analysis, capital budgeting etc.

(ii) Marketing

(iii) Purchasing

(iv) Production management

(v) Maintenance management

(vi) Personnel management

(vii) General Management:

Deision Support Systems (DSS), M.I.S, Forecasting, Effective Quality controlling, Strategic planning etc

(viii) **Government: Applications** are found in Economic planning, optimal use of natural resources and energy, Urban and housing planning, Strenghening Armed forces etc.

10. Standing of O.R. in the real world:

Some of the negative impressionscreeped in in the minds of sections of users look like;

(i) Being looked upon as an esoteric science (ii) Not being applied as it should be

Hence, the bottom line is that an O.R. application can be successful only if sufficient attention is paid to each of the steps of the process and in the ability to communicate results to the end-users in an understandable form.

11. Limitations of O.R:

1. Costly: Operations Research (OR) could be costly. This is because O.R makes mathematical models for taking decisions and solving problems. The O.R Team necessarily has to make various models for solving different problems. All this increment the cost.

2. Not Realistic

3. Complex

12. Role of O.R .In India-A Brief:

Even in the present turbulent times, India has been transforming as one of the most important economic nations .It would be interesting to recall on the introduction of O.R in the country.

The second half of 20th century heralded the introduction & use of O.R in India, after becoming an Independent nation in 1947. O.R came into existence in 1949 at Regional Research Laboratories (RRL), Hyderabad for planning and organizing its multi-faceted research activities. Imperial Chemicals India Ltd (I.C.I.Ltd), ORGI(Operations Research Group of India (Established by late Sarabhai, patriot & industrialist) and a few MNCs were the pioneers.The Armed forces,IITs & Indian Statistical Institute (I.S.I),Kolkata ,amongst others, are rendering an yeoman service towards popularizing and furthering the cause of O.R with strong research based faculty.

13. The O.R.Applications in Mining Organisations in India:

7 Nos. of actual applications are dwalt in this paper and listed as follows.

(i)Production Planning Application
(ii)Materials Management Application:
(iii)Waiting Line Application:
(iv)Work sampling Application:
(v)Make or buy decision coupled with the sensitivity analysis - Project formulation Application
(vi.)Network Management Application
&vii) Simulation Application
The details are placed at the end.

14. O.R & Its positive Interventionary role vis-a-vis globalization:

Due to the advent of Globalization, a plethora of measures; such as SoPs (Standard Operating Procedures), Technogy Transfers, CAD, CAM, Consultancies etc have been ushered in improving the operations of various corporates. In such corporates that economic market favours (sellers'markets),where Profit& Profitability are inevitable, a need still exists to continue to utilize O.R, which, in its wake ensures conservation of Resources ,especially ,the physical ones, which is rather any nation's priority.

On the other hand, the other type of organizations, ipso- facto, any how, are destined to utilize O.R to with stand competition and to remain in market for ushering in rationalization of costs that O.R yields in the role of "a-friend-in -need –is-a friend-in-deed".

Accordingly, it is earnestly felt that when O.R. is also accorded its DUE IMPORTANCE, then the Value addition system might ensure reduction in production cost, thus helping the CUSTOMER to obtain products and Services at marginally lower Sale prices. This, in turn, is likely to generate more of real savings that accrue to the people, out of which at least some portion may inevitably get plouged back as investment in the economic system comprising of various sectors, thus aiding in economy growth of any nation.

Thus,the more the use of O.R is, the better it would be for the end Customer, which eventually leads to enhacement of Quality of life in the Nation.

Details of Item 13
The O.R. PRACTICAL APPLICATION IN MINING ORGANISATIONS IN INDIA
7 Nos. of O.R Applications are presented here under.

O.R APPLICATION (I):
Production Planning Application

The techniques is applied to decide Mine wise annual production targets located at a geographical location covering a group of Mines so as to get maximum profit,with subjected to a certain set of Constraits

Technique used: Linear Programming.

L.P Problem formulation;

There are 3 Mines (A,B&C) producing mineral at a geographical Location(Called Area), each Mine using a different level of technology, capable of producing the specified mineral of its distinct grade and having different manning needs.The Mines operate round the clock and the following data is finalized by the Management Services Department(Known as Industrial Engineering Department). It is prepared in consultation with and agreement of Mining function (Production Department), Finance Function, Quality control Department Etc and the parameters are approved by the General Manager, to avoid subsequent differences of opinion.

(i)There is a total pool of man power of 3400 numbers of manpower reservoirs, comprising both on-roll employees and a complement of Labour pool on out- sourced basis. Thus the production combination can be such that the total need of man power resources must not exceed 3400 Nos.at the area level.

(ii)There is everneed for maintaining a Quality level of the output of the mineral, as it is stipulated by end customer that is mutually monitored by enforcement of mineral (Quality) Supply Agreements (MSAs) that impose both penalties and Incentives based on Quality levels being sent. The organization follows the practice of mixing the outputs from the 3 mines for obtaining the desired composite grade and the mixed mineral is dispatched to the customers. The Minimum Composite Grade of Quality stipulated by Customer is 1.38.

(iii)The mine wise Annual capacities are 2.50,1.50&10.0 Lakh Tonnes & Area Total is 14.0 Lakh Tonnes.

(iii)The mine wise profit/Tonne is different based on specifics of Manual and mechanization components and the relative resulting costs incurred and the costing system is based on Direct Standard Costing (D.S.C) System. Like any Corporate, there is ever need to maximize profit.

S.No	Mine	Annual Mine	Profit/	Manning Norm(numbers /	Mine Wisel grade

		capacity(Lakh Tonnes)	Tonne (Rs)	1 Lakh Tonnes of coal out put)	(Nature Endowed)
1	A	2.50	40	500	2.00
2	B	1.50	-60	600	3.00
3	C	10.00	400	125	1.00
	Total	14.00			

The Question is deciding on the Annual targets for each of these mines, subject to the constraints.
The Problem is solved by Linear Programming (L.P) Method.

L.P.Formulation:

Let Annual Production Targets (in tones) for Mines A, B& C be X_1, X_2 & X_3 , respectively.
Then, the Objective function is
Maximise $40X_1 - 60X_2 + 400 X_3$ ..... Maximising Profit

Subject to the constraints:

$500X_1+600X_2 +125X_3 <= 3400$ …(1)Man Power Availability constraint
$(2X_1 +3X_2 + X_3) /$
$(X_1 +X_2 + X_3)$ >= 1.38……..... (2)Composite Grade to be maintained
$X_1 +X_2 + X_3$ <=1400000……. (3)Annual Production Need
X_1 <=250000……... (4)Annual Capacity of Mine A
X_2 <=150000…..……... (5)Annual Capacity of Mine B
X_3 <=1000000……..…. (6)Annual Capacity of Mine C
X_1 ,X_2 , X_3 >=0…….(7)Annual Production targets of Mines A,B& C

O.R APPLICATION (II):

Materials Management Application:

Materials management plays a significant role in the life of an organization, as around 50 to 60% of the cost of production is accounted by the Materials.Better management of this function yields good results.

By utilizing the O.R concepts as related to Materials Management, the following list of activities are carried out

(i)ABC, VED &XYZ Categorisations, Q&P Systems, Fixing material consumption norms for A Category items etc

(ii)Even before the advent of computers, classification and codification of materials was handled, the benefit being considerable by successfully avoiding duplication and obsolescence.

The enlightened management implemented a decision of posting Industrial Engineering trained Executives in the Materials Management functions ,such as ;Purchase, Stores,Invetory control functions, to help the line management of Materials Management.who rendered an yeomen service , thanks to the O.R.Concepts.

Financial Savings per year in the Mining Organisation:

Total Annual Income
Including Sales Realization: Rs 12,212 Crores
Cost of Production : Rs 11,662 Crores
"Profit Realized : Rs 550 Crores"

In the Cost of Production of Rs 11,662 Crores, Materials accounted for Rs 2302 Crores, amounting to as much as 19.7% (2302 X 100/11662). The Average value of inventory from Stores Records is Rs 425 Crores, working out to 0.185 year equivalent Stock (425/2302) or 2.22Months equivalence.

Prior to systemetisation of inventory management with O.R.Applications, the average inventory was in the range of 0.5 year or equivalent of 6 months Average Inventory.

Thus, the reduction of average inventory works out to 6.00 – 2.22 = 3.78 Months.

In turn, its monetary value works out (3.78/12.0) X 2302 = Rs 725 Crores

At an average annual carrying cost of 20%, this amounts to 0.20 X 725 = Rs 145 Crores.

Put in another way, the Profit Realized, instead of 550 would have been reduced to: Rs 550 – 145 = 405 Crores.

Benefit of O.R.Application:

(i)Improvement in Profit: As brought out above

(ii) And more important aspect is the less locking of the Precious Material in the Stores in the organisation, which obviously could be then available to other organizations (Live and Let Live or Win-

Win concept at national level), as in the Case with the World Class Best Practice called JIT Purchase adopted by Japanese Corporates.

O.R APPLICATION (III):

Waiting Line Application:

Mining Organisations, per force, are located, not at preferred places & locations but at places where the mineral is available. Accordingly, they have to invest more in services such as Health, Education etc. At all areas (a place where about 5 mines are operated), townships are built for employees with various related amenities.

Concepts of Queing models are utilized in deciding the no. of registration desks at hospitals, no. of ambulances, paramedical staff etc,.to name a few.

Within the ambit of mining operations, waiting model concepts are utilized in deciding Optimum Equipment combination,.such as , Per Excavator,the Dumper Fleet combination requirements, in view of high down time cost of equipments per unit time

O.R APPLICATION (IV):

Work sampling Application:

Work sampling is a simple to administer to technique that basically decides the idleness/Occupation of a Resource (Man, Machine etc.)

Utilization of this concept resulted in arriving at production standards, quickly and at a lesser cost (A Popular USA Work Measurement technique).

Under proper design, it can be used to arrive at rational man power requirements.

The mining organizations continuously make use of Work sampling techniques.

O.R APPLICATION (V):

Make or buy decision coupled with the sensitivity analysis - Project formulation Application

Economies of establishing captive chemical plant: The Mining organisation has been "buy"ing an important chemical product "X", from 3 plants established on its premises to be used in its own down stream production operations. The supply was not smooth and was resulting in disruptions of down stream operations.

A committee has been constituted to prepare a conceptual Report on feasibility of exploring options of having Plants functioning under its management so as to "make" the product and to offer to the management various options considering raw material supply position / arrangements, cost assessment and cost- benefit analysis. This is a good O.R Case concerning make or buys decision coupled with the sensitivity analysis and inevitable cost-benefit analysis (C.B.A)

The Committee Members are drawn from different disciplines.

1.0 **Scope of work:**

Scope of the work of the committee is to familiarization with the existing system of supply of the product **"X"(the chemical),** make visits to the existing operating Plants located in the premises and else where to familiarize with and study the method of production, processes and constraints, examine the various alternative production system models to produce the product, make Cost-Benefit Analysis and to prepare a recommendations on the subject and place before management to enable it to take decision.

2.0Methodology:

i) Initial meetings for familiarization and to carry out thread bare discussions on the subject.

ii) Analyse consumption & future requirement of "X" for use by organisation.

iii) Make visits to the existing operating plants in the premises and elsewhere to observe the products and processes.

iv) Evolving various alternatives of producing the product"X",considering the existing constraints experienced at the down stream user department/s to sustain uninterrupted and smooth availability .

v) Carry out sensitivity analysis and cost-benefit analysis for various alternatives for producing the product by organization itself &

vi) Present Recommendations for taking decision by Management.

3.0 Observations:

i) The product is critical and the lifeline in the down line production activity.

ii) It should be made available in right quality, quantity and right time.

iii) Presently, the product"X" is obtained from out sourced agencies, based on open tendering process and linked to concept of guaranteed Performance Factor (P.F). The P.F essentially determines yield factor of Co.'s final output per unit of the product "X" used.

iv) No substantially large investment is needed for setting up of a Captive Plant, to make this chemical product.

v) In view of the low cost of making, some of the successful bidders established Plants on the premises of organisation.

vi) The then Ruling order price of the chemical was Rs. 19,101.46 per Metric Tonne (Considered as Base Price in the analysis).

vii) The manufacturing technology for Product "X" involves procuring and chemical processing of various constituent materials procured with fluctuating prices from various sources in the country.

vii) During the immediate past , the mining organisation suffered from shortage / interrupted supply of this product"X" on number of occasions and production got affected to an extent of 5%.

viii) However, the Plants alleged that the shortage / interruption were mainly due to inconsistent supply / availability of raw material from their various supply sources and that the prices also had been fluctuating violently from time to time.

ix) In this back drop,the Management of the Mining organization, realized thata need exists to have an institutionalized arrangement for analyzing options of buying/lease taking/establishing own captive plants for making this Product' X" .

4.0 Study of available options:

In the aforesaid back ground, the committee analyzed the topic of having the Chemical Plant under the management, and examined three options by utilizing O.R approach(especially,the techniques of Sensitivity anlysis & Cost –Benefit Analysis (C.B.A);

The 3 Options / Alternatives (Alt) are;

Alt 1. Negotiating & taking on lease the existing Plants being operated by outside Agencies.

Alt 2. Negotiating & Purchasing these existing Plants being operated by outside Agencies.

Alt 3. Establishing Own Captive (New) Plants.

While constructing these options, it was kept in mind that major portion of operations are to be "Manned" (carried out), by out sourcing.

Each of these options will ensure timely availability of the Material "X" and facilitate good yield factor, resulting in improved production and productivity in the Mining organisation.

5.0 Recommendations:

Considering the above observations, Recommendations are put up to Management in terms of 3 Options, in this order of priority.

5.1 Alternative –1 & (Priority–1)

Taking on lease of the existing Suppliers'plants, with major portion of out sourcing of all the connected operations

5.2**Alternative –2 & (Priority –2)**

Purchasing of the existing Suppliers'plants, with major portion of out sourcing of all the connected operations

5.3**Alternative –3 (& Priority –3)**

In case Alternative –1 and 2 indicated above do not materialize, establishing new GREEN plants at the locations of existing Suppliers' plants will become the Alernative-3, again with major portion of out sourcing of all the connected operations.

6.0 **Cost- Benefit Analysis:**

Cost benefit exists for each of these 3 courses of action plan.

In physical terms, the captive plants will help to improve the Overall Out put production rates of the mining organisation.

Details are placed here under.

1.0 EXISTING METHOD (Material "X" being bought)	
Materia l "X" : Purchase Price (Rs/Tonne)	**19,101.46**

2.0 Estimated Costs for 3 Options				
Alternative No.,	Type	Estimated Cost (Rs/Tonne)	Varience Over Existing Method (Rs/Tonne)	% increase Over Existing Method

(1)	(2)	(3)	(4)	(5)
Existing Cost (Base Cost)		**19101.46**	-	-
I	Lease	19747.00	645.54	3.38%
II	Buy	19808.00	706.54	3.70%
III	New Plant	20636.00	1534.54	8.03%

3.0 Production & Cost Data (For Base Year)	
(1)	(2)
ITEM HEADING	**Quantity**
Production Output (In Million Tonnes) (M.T) (Base Production)	17.90458
Avg. Sales Realisation (In Million Rupees)	20289.00
Avg. Sales Realisation (Rs/Tonne)	1133.17
Total Cost (In Million Rupees)	11228.40
Total Cost (Rs/Tonne)	627.12
Profit (In Million Rupees)	9060.60
Profit (Rs/Tonne)	506.05
Material "X" Cost (In Million Rupees)	434.60
Material "X"Cost (Rs/Tonne)	24.27

4.0 Cost Benefit - Cum- Sensitivity Analysis (CB-c-SA)

ASSUMPTIONS:

A) (1) In all Alternatives, the Plants are managed by the Mining Organisation itself.

(2)Timely availability of the Material reduces Production inturruptions & production loss.

B) Material Availability will become uninturrepted.

C) (1) For conducting CB-c-SA, a Notional 1% improvement in production is considered (which has been found feasible,as an average ,5% of output is lost, due to timely non-avalability of this Materal., being bought),

(2) More over, the production **department estimated that uninturrepted availability** of this material would result in minimum 4% improvement in Production

4.1 : ALTERNATIVE I			
ITEM HEADING		**Assumption**	**Assumptn**
	ALT-E	ALT-1	ALT-1
	(Existng System)	Lease the Plants	Lease the Plants
(1)	(2)	(3)	(4)
1.% Increase in Production output	NIL	1%	With No change in Scenario
2.% Increase in Material Cost	NIL	3.38	3.38
3.Production Output, In Million Tonnes (M.T)	17.90458	18.0836258	17.90458
4. (EQUIVALENT Index No.)	100	101	100
5.Avg. Sales Realisation (In Million Rupees)	20289.00	20491.89	2028.90
6.Avg. Sales Realisation (Rs/Tonne)	1133.17	1133.17	1133.17
7.Total Cost (In Million Rupees)	11228.40	11298.90	11243.10
8.Total Cost (Rs/Tonne)	627.12	624.81	627.94
9.Profit (In Million Rupees)	9060.60	9193.00	9045.90
10.Profit (Rs/Tonne)	506.05	508.36	505.23
11.Material Cost (In Million Rupees)	434.60	453.78	444.29
12.Material Cost (Rs/Tonne)	24.27	25.09	25.09
13. (EQUIVALENT Index No.)	100	103.3932854	103.393285

4.2 : ALTERNATIVE II			
ITEM HEADING		**Assumptn**	**Assumptn**
	ALT-E	ALT-2	ALT-2
	(Existng	Buy the	Buy the
	System)	Plants	Plants
(1)	(2)	(3)	(4)
1.% Increase in Production output	NIL	1%	With No change in Scenario
2.% Increase in Material Cost	NIL	3.7	3.7
3.Production Output, In Million Tonnes(M.T)	17.90458	18.0836258	17.90458
4. …...do…. (EQUIVALENT Index No.)	100	101	100
5.Avg. Sales Realisation (In Million Rupees)	20289.00	20491.89	2028.90
6.Avg. Sales Realisation (Rs/Tonne)	1133.17	1133.17	1133.17
7.Total Cost (In Million Rupees)	11228.40	11300.30	11244.40
8.Total Cost (Rs/Tonne)	627.12	624.89	628.02
9.Profit (In Million Rupees)	9060.60	9191.60	9044.60
10.Profit (Rs/Tonne)	506.05	508.28	505.15
11.Material Cost (In Million Rupees)	434.60	455.19	450.68
12.Material Cost (Rs/Tonne)	24.27	25.17	25.17
13. …...do…. (EQUIVALENT Index No.)	100	103.713327	103.7133

4.3 : ALTERNATIVE III			
ITEM HEADING		**Assumptn**	**Assumptn**
	ALT-E	ALT-3	ALT-3
	(Existng	Establsh	Establsh
	System)	New Plant	New Plant
(1)	(2)	(3)	(4)
1.% Increase in Production output	NIL	1%	With No change in Scenario
2.% Increase in Material Cost	NIL	8.03	8.03
3.Production Output, In Million Tonnes(M.T)	17.90458	18.0836258	17.90458
4. …...do…. (EQUIVALENT Index No.)	100	101	100
5.Avg. Sales Realisation (In Million Rupees)	20289.00	20491.89	2028.90
6.Avg. Sales Realisation (Rs/Tonne)	1133.17	1133.17	1133.17
7.Total Cost (In Million Rupees)	11228.40	11339.30	11263.30
8.Total Cost (Rs/Tonne)	627.12	627.05	629.07
9.Profit (In Million Rupees)	9060.60	9152.60	9025.70
10.Profit (Rs/Tonne)	506.05	506.12	504.10
11.Material Cost (In Million Rupees)	434.60	474.19	469.50
12.Material Cost (Rs/Tonne)	24.27	26.22	26.22
13…..do…. (EQUIVALENT Index No.)	100	108.043883	108.04388

5.0 Observations Summary at a Glance			
5.1 Observations Summary at a Glance		**Assumption**	**Assumptn**
	ALT-E	ALT-1	ALT-1
	(Existng	Lease the	Lease the
	System)	Plants	Plants
(1)	(2)	(3)	(4)

1. +/- In Production Output	Base 179.0458	0.179	0
2.+/- In Total Cost (In Million Rupees)	Base 11228.40	70.50	14.70
3.+/- In Total Cost (In Rs/Tonne))	Base 627.12	- 2.31	0.82
4.+/- In Profit (In Million Rupees)	Base 9060.60	132.40	- 14.70
5. +/- In Profit (In Rs/Tonne)	Base 506.05	2.31	- 0.82
6. Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.26	
7.BE Output Required (In Million Tonnes)As against Existing 17.90 M.Ts))		17.951	
8. % Incr in Output needed for achieving B.E		0.26	

1

5.2Observations Summary at a Glance		**Assumptn**	**Assumptn**
	ALT-E	ALT-2	ALT-2
	(Existng	Buy the	Buy the
	System)	Plants	Plants
1.+/- In Production Output	Base 179.0458	0.179	0
2.+/- In Total Cost (In Million Rupees)	Base 11228.40	71.90	16.00
3.+/- In Total Cost (In Rs/Tonne))	Base 627.12	-2.23	0.90
4.+/- In Profit (In Million Rupees)	Base 9060.60	131	-16.00
5.+/- In Profit (In Rs/Tonne)	Base 506.05	2.23	-0.90
6. Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.29	
7.BE Output Required (In Million Tonnes)As against Existing 17.90 M.Ts))		17.957	
8. % Incr in Output needed for achieving B.E		0.29	
5.3 Observations Summary at a Glance		**Assumptn**	**Assumptn**
	ALT-E	ALT-2	ALT-2
	(Existng	Establsh	Establsh
	System)	New Plant	New Plant
(1)	(2)	(3)	(4)
1.+/- In Production Output	Base 179.0458	0.179	0
2.+/- In Total Cost (In Million Rupees)	Base 11228.40	110.90	34.90
3.+/- In Total Cost (In Rs/Tonne))	Base 627.12	-0.07	1.95
4.+/- In Profit (In Million Rupees)	Base 9060.60	92	-34.90
5.+/- In Profit (In Rs/Tonne)	Base 506.05	0.07	-1.95
6. Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.62	
7.BE Output Required (In Million Tonnes)As against Existing 17.90 M.Ts))		18.016	
8. % Incr in Output needed for achieving B.E		0.62	

6.0 SUMMARY OF FINAL RECOMMENDATIONS:			
6.1SUMMARY OF FINAL RECOMMENDATIONS:		**Assumption**	**Assump**
Ranking of Cost Benefit &SenstvityAnalysis indicates" ALT 1, **(Priority I)**	ALT-E	ALT-1	ALT-1
(viz, Lease the Existing Plants)	(Existng System)	Lease the Plants	Lease th Plants
This analysis is submitted for Management to make a decision			
(1)	(2)	(3)	
ITEM			
Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.26	
BE Output Required (In Million Tonnes) As against Existing 17.90 M.Ts))		17.951	
% Increase in Output needed for achieving B.E		0.26	

6.2 SUMMARY OF FINAL RECOMMENDATIONS:		**Assumptn**	**Assumptn**
Ranking of Cost Benefit &SenstvityAnalysis indicates" ALT II , **(Priority II)**	ALT-E	ALT-2	ALT-2
(viz, Buy-off the Existing Plants)	(Existng System)	Buy the Plants	Buy thePlants
This analysis is submitted for Management to make a decision			
ITEM			
Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.29	
BE Output Required (In Million Tonnes) As against Existing 17.90 M.Ts))		17.957	
% Increase in Output needed for achieving B.E		0.29	

6.3 SUMMARY OF FINAL RECOMMENDATIONS: (Priority III)		**Assumptn**	**Assumptn**
Ranking of Cost Benefit &SenstvityAnalysis indicates" ALT III,**(Priority III)**	ALT-E	ALT-3	ALT-3
(viz, Establish New Plants)	(Existng System)	Establsh NewPlant	EstablshNew Plant
This analysis is submitted for Management to make a decision			
ITEM			
Break Even (BE) Output (Addl Output) (Equivalent Index No.)		100.62	
BE Output Required (In Million Tonnes)As against Existing 17.90 M.Ts))		18.016	
% Increase in Output needed for achieving B.E		0.62	

7.0 Checks and Balances:

i) Proper Quality of the product's checking is to be evolved before it is delivered from Plant and its Vehicles.

ii) For better cost benefit, the Co. has to properly monitor the the product's consumption.

iii) Proper recording system regarding movement of both inputs as well as final product at all user sections is to be evolved.

iv) Proper mechanism to prevent wastage of the product, if any, is to be evolved.

v) Constant R&D is required to keep abreast on the developments in the field associated with this product

8.0 Conclusions:

i) In view of the criticality of uninterrupted supply position of this critical product X in right quantity, quality and right time, the 3 alternatives listed above, ramked in the order of priority, will help in consolidating the performance of the mining organization and in improving its gross physical and financial performance which is the cherished goal of any corporate/Entity.

ii).The committee being only recommendatory, these Recommendations is formally put up for decision by Management, as it alone is vested with the authority to take the FINAL DECISION.

O.R APPLICATION (VI):

Network Management Application

This is an approach to planning, scheduling and controlling complex projects.

Mining operations are both interesting and challenging, as one has to deal with nature endowed parameters and Challenges.Mine is a physical entity carved out of earth. While it is so, for both initiating as well as construction of a mine, O.R.Methodologies like Net work planning is found to be vital, as unlike surface installations like; factories and Sevice structures, the Project construction time periods are large.

The corporate Planning function that is charged with the function of preparation of feasibility reports for mining projects extensively uses these techniques. Considerable time & cost over runs are saved.

O.R APPLICATION (VII):

Simulation Application

It is said that Simulation is an imitation of Reality and mainly it studies behavior of Resources and processes over time. Among its different types, Monte Carlo method has been time tested and is considered as a popular one.

An example of assessing the number of fire tenders needed at a mining organisation

Mining organizations are usually located at locations predominantly dictated by Nature itself.

In the mining organization, among others, initially, a fire station with a certain minimum no. of fire tenders is established, based on industry practices. The location point itself is important and done at centre of Gravity

of various activity centres. (Incidently, O.R. also aids in Location decision).Over a period of time, proposal emanated for adding more no. of fire tenders.

The question has arisen whether to agree to the proposal in toto or accord approval with modification or to reject.

It may be kept in mind that the consequences may be favourable or detrimental, as stated here under.

If more fire tenders are added without commensurate use, financial loss accrues to the organization.On the other hand, if need is there and the no of fire tenders is insufficient, there will be considerable loss in terms of damage to equipment,materials or cause even human loss.

Hence the decision needs to be taken, prudently.

Scope:

Simulation technique makes prediction of likely pattern possible, mainly being based on the assumption that the likely behavior of the system closely follows the pattern indicated by the available historic data.

Basis for selection of Simulation technique:

i) It would be impractical and too expensive set up a designed experiment, using the real process, due to excessive time constraint or the very nature of the process.

ii) The problem could be solved within the time frame specified by management.

Methodology:

1. Referral to historical data:

The history records of fire occurances have been collected and tabulated in a chronological order and the information is collated with special reference to the following heads:

i) Successive dates of fire occurrences

ii) Exact time of occurrence and receipt of information on the same at fire station

iii) Fire duration in hours or part of it.

iv) Nature of fire & Cost of damage occured, in monetary terms.

v) Plant/Equipment/Building/Specific geographical location etc.

2. Analysis of (afore mentioned) recorded data:

(a) Frequency distribution of time interval between two successive fire accidents, in days: (x_1)

Interval X_1	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Prob ($x_1 = X_1$)	0.143	0.179	0.143	0.143	0.035	0.108	0.000	0.072	0.035
Cum Prob ($x_1 = X_1$)	0.143	0.322	0.465	0.608	0.643	0.751	0.751	0.823	0.858
Interval X_1	9	10	11	12	13	14	15	16	
Prob ($x_1 = X_1$)	0.072	0.000	0.000	0.035	0.000	0.000	0.000	0.035	
Cum Prob ($x_1 = X_1$)	0.930	0.930	0.930	0.965	0.965	0.965	0.965	1.000	

(b)Frequency distribution of Shift wise occurrence of Fire accidents (x_2)

Shift X_2	**A(6Am-2Pm)**	**B(2Pm-10Pm)**	**C(10PM-6AM)**
Prob ($x_2 = X_2$)	0.276	0.517	0.207
Cum Prob ($x_2 = X_2$)	0.276	0.793	1.000

(c)Frequency distribution of Inrashift occurrence of Fire accidents at 1 hour intervals (x_3)

(i)Shift A: (x_{3A})

Shift A:(x_{3A})	**Ist hour**	**2 nd hour**	**3rd hour**	**4th hour**	**5th hour**	**6th hour**	**7th hour**	**8th hour**
Prob ($x_{3A} = X_{3A}$)	0.083	0.083	0.000	0.083	0.330	0.250	0.083	0.088
Cum Prob($x_{3A}=X_{3A}$)	0.083	0.166	0.166	0.249	0.579	0.829	0.912	1.000

Shift B:(x_{3B})	**Ist hour**	**2 nd hour**	**3rd hour**	**4th hour**	**5th hour**	**6th hour**	**7th hour**	**8th hour**
Prob (x_{3B} =X_{3B})	0.130	0.130	0.130	0.220	0.130	0.130	0.090	0.040
Cum Prob(x_{3B}=X_{3B})	0.130	0.260	0.390	0.610	0.740	0.870	0.960	1.000
Shift C:(x_{3C})	**Ist hour**	**2 nd hour**	**3rd hour**	**4th hour**	**5th hour**	**6th hour**	**7th hour**	**8th hour**
Prob (x_{3C} =X_{3C})	0.200	0.100	0.100	0.100	0.000	0.000	0.100	0.400
Cum Prob(x_{3C}=X_{3C})	0.200	0.300	0.400	0.500	0.500	0.500	0.600	1.000

(d) Type wise Fire Tender pressed into service: (x_4)

The following type wise fire tenders; water tanker, Jeep with water trailer or Both are put use, depending upon nature and intensity of fire accident

Interval X_4	**W (I No.,) (Water Tanker)**	**J (1 Nos.,) (Jeep& Water Trailer)**	**B(2 Nos.,) (Both)**
Prob (x_4 = X_4)	0.52	0.41	0.07
Cum Prob (x_4 = X_4)	0.52	0.93	1.00

These variables, viz., x_i, i= 1, 2, 3 &4 are subjected to Monte Carlo simulation.

Other data:

(e) Average duration of Fire accident = 0.75 Hours (as Per Records)

(f) Average damage value per occurrence = Rs 1000 (From Records)

3. Monte Carlo Simulation Process:

The Parameters x_i, i= 1, 2, 3 &4 may be difficult to visualize in contrast to repetitive processes.

The Monte carlo simulation process hence utilizes concept of random numbers. For this, all the previously mentioned Frequency distributions are made into equivalent tabular presentations, utilizing numbers in 3 digits to 6 digits.

Table 1:Source(a)Frequency distribution of time interval between two successive fire accidents			Table 2:Source(b):Frequency distribution of shiftwise occurrence of fire accidents	
Random Nos.Range	Interval (in days)		Random Nos.Range	Shift
000000 – 143000	0		0000 – 2760	A
143001 – 322000	1		2761 – 7930	B
322001 – 465000	2		7931 – 9999	C
465001 – 608000	3			
608001 – 643000	4			
643001 – 751000	5			
	6			
751001 – 823000	7			
823001 – 858000	8			
958001 – 930000	9			
	10			
	11			
930001 - 965000	12			
	13			
	14			
964751 – 965000	15			
985001 – 999999	16			

Table3:Source(c):Frequency distribution of intrashift fire accidents at hourly intervals					Table 4 :Source(d): Frquency distribution of type of fire tender used	
No.of hourly interval	Shift-A	Shift-B	Shift-C		Random Nos.Range	Type of Fire Tender used
1	00000 – 08300	0000 – 1301	000 – 200		000 - 520	W
2	08301 – 16660	1302 – 2600	201 – 300		521 - 930	J&T
3		2601 – 3900	301 - 400		931 - 999	Both
4	16661 – 24900	3901 – 6100	401 – 500			
5	24901 - 57900	6101 – 7400				
6	57901 – 82900	7401 – 8700				
7	82901 – 91200	8701 – 9600	501 – 600			
8	91201 – 99999	9601 - 9999	601 - 999			

4. Simulation Runs:

(i) A set of random nos. have been used, to predict timing of successive fire accident occurrences.With reference to Table 1, the interval(x_1) between successive fire occurrences is obtained corresponding to the random number used. For ex., assuming the reference date of first occurrence is assumed as 0^{th} day and if the random no.is 612963, then $x_{1\ is}$ 4. Thus the successive expected fire oocurence is on 4^{th} day (Clock calendar).The simulation is continued. When the clock calendar completes 365 days, it corresponds to 1 year and so on. The no. of likely occurrences will match with the no. of Random Nos. used (N).

(ii) Table 2 aids in predicting the corresponding shift for each of the expected fire occurrence on days predicted earlier (as per step (i) above).(iii) Similar iteration deals with the fire accident that occur on hourly basis in the Shift.(iv) The final step deals with the type of equipment pressed into Service.

The above analysis also shows that to simulate N-sets of prediction, a total of 4N random numbers are to be used to deal with the total system.

Part of simulation Results look as follows

Cumulative Clock time (days)	Shift	Hourly interval in the shift	Type of Fire tender/s used
0 (Ref)			
4	A	6 th	W
11	B	4 th	W
16	B	3 rd	J
21	A	5 th	B
21	B	2 nd	J
36	A	6 th	J
43	C	3 rd	J
45	A	2 nd	W
Etc			

5. Results from simulation Run:

1. Main findings

(i) Avg no. of Fire accidents/ month = 7

(ii) Avg .no of Fire tenders needed/Occasion =1

2. A total of 2 nos of fire tender (with 1 as standby) and corresponding round the clock manning is to be ensured.3. Occurrence of 2 or more simultaneous fire accidents are expected to be very rare. It is expected that once in 2.5 years, this may occur. To meet such a rare eventuality, all the firemen of the back shifts are to be summoned and put to service.

6. Suggested Areas of Application

(i) Ambulance facilities (ii) Out patient Service Counters (iii) Distribution of Police Petrol Cars (iv) Epedemics forecast&control (v) Planning of Tourist facilities (vi) Runways at airports (vii) Disasters management (viii) Traffic lights configuration..etc

References

1.Principles and applications of operations research(From Maynard's Hand Book,5th Edition,pp 11.27-11.44) Jayant Rajgopal,Department of Industrial Engineerinh,University of Pittsburgh,Pensilvania

2. J.K.Sharma (2013), O.R Theory&Applications, 5th Edition, Macmillan

3. https://www.britannica.com/topic/operations-research/Essential-characteristics(2017)

4. www.businessmanagementideas.com/personnel-management/operation-rese(2017)