PRODUCTION OPTIMIZATION AND SIMULATION OF LARGE OPEN CAST MINES

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PRODUCTION OPTIMIZATION AND SIMULATION OF LARGE OPEN CAST MINES

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by

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Under the guidance of

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CERTIFICATE

This is to certify that the thesis entitled "**PRODUCTION OPTIMIZATION AND SIMULATION OF OPEN CAST MINES"** Submitted by **Uttam Ghorai** to National Institute of Technology, Rourkela, is record of bona fide research work under our supervision and we consider it worthy of consideration for the award of the degree of Master of Technology (by Research) of the Institute.

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Date: April 29, 2011

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DECLARATION

a) The research work in this thesis is original and has been done by myself under the general supervision of my supervisor.
b) The work has not been submitted to any other Institute by any one for any degree or diploma.
c) I have followed the guidelines provided by the Institute in writing the thesis.
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e) Whenever I have used any data or theoretical analysis or text from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references.
f) Any quoted materials from other sources, put under quotation mark, giving details in the reference.

UTTAM GHORAI

LIST OF SYMBOLS AND ABBREVIATIONS

AT	=	Arrival Time
LAT	=	Last Arrival Time
IAT	=	Inter Arrival Time
IATSR	=	Inter Arrival Time Sub-Routine
ILT	=	Inter Loading Time
ILTSR	=	Inter Loading Time Sub-Routine
CLET	=	Current Load End Time
PLET	=	Previous Load End Time
LBT	=	Load Begin Time
DWT	=	Dumper Wait Time
SWT	=	Shovel Wait Time
TDWT	=	Total Dumper Wait Time
TSWT	=	Total Shovel Wait Time
ADWT	=	Average Dumper Wait Time
AILT	=	Average Inter Loading Time
RN1	=	Random Number 1
RN2	=	Random Number 2
ADWT	=	TDWT/Count
IATSR	=	IASR/ (RN1=IAT)
AILT	=	TILT/Count
ILTSR	=	ILTSR/ (RN2=ILT)
C	=	Pay load capacity of the trucks in tons

F	=	Fill factor for trucks
K	=	Co-efficient for truck utilization
M	=	No of faces working simultaneously in the mine,
N	=	No of trucks employed per shovel
Db	=	Backward haul distance in kms.
df	=	Forward haul distance in kms
q	=	Output from a truck in an hour,
Q	=	Face output per hour,
t1	=	Truck loading time in min.
tf	=	Forward haul time for the truck in min.
tb	=	Backward haul time for the truck in min.
td	=	Time required for dumping and turning for the truck near the . primary crusher in min.
ts	=	Spotting time for truck near the shovel in min.
tsh	=	Cycle time for the shovel in min.
T	=	Total cycle time for trucks in min.
Vb	=	Backward haul velocity in km/hr
Vsh	=	Specific volume of shovel in cubic meter
γ	=	Density of broken material in tons/cubic meter
μ	=	Mean for the normally distributed random number
σ	=	Standard deviation for the normally distributed random Number.
m	=	No of faces working simultaneously in the mine.
Fsh	=	Fill factor of the shovel,
Xi	=	i th pseudo-random number where i is an integer
Xi+1	=	Next pseudo-random number of Xi
Xo	=	Initial value of Xi (called the seed)

X1,X2,..Xd	=	Independently and identically distributed random variables up to d-th term
Ri	=	Distribution Number
Ri+1	=	Actual distribution number,
Ro	=	Any number between 1 to 10,000
X	=	Mean of the number
U (0,1)	=	Distribution function between 1 to 10,000
E	=	Expectation of occurrence
V	=	Variance in occurrence
R1, R2, R3, R4	=	normally distributed random number
d	=	Total number of terms considered for distribution function
UNRAND	=	uniformly distributed random number,
NORAND	=	normally distributed random number
CE	=	Relative capital expenditure in Rupees
IC	=	Capital investment in Rupees
Qc	=	Commercial reserve in tons
RE	=	Relative revenue expenditure in Rupees
TRE	=	Total revenue expenditure during the life of the mine, in Rs

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The impact of production optimization and scheduling mainly depends on availability of the machineries; their break-down maintenance schedule and minimization of their idle time i.e. increase in their availability which maximizes their utility. The simulation work-sheet prepare here for the same purpose only for shovel-dumper transport system. In next phase all the machineries are analyzed of their break-down record by random number distribution for preventive maintenance so as to minimize the same and increase their availability in work condition to maximize productivity and hence production optimization.

Simulation Work-Sheet developed here states that if one or more dumper is added in the system. There is no need for a dumper to wait in the queue. But, before effecting any decision, the cost of having an additional shovel has to compare with the cost due to dumper waiting time.

The breakdown of different machineries is analyzed with random number distribution. The different event falls under definite random number distribution range. Such as if random number comes as 1 - 6875 indicates the shovel breakdown and if it comes 6876- 13125 it will be considered as dumper break-down, etc. Hence a clear idea can be made for the break-down of different machineries also precautions can be taken for preventive maintenance to minimize these break-down periods by analyzing this method and thus production can be set as Optimum and steady-state.

Keywords: Production scheduling, Simulation, Break-down, Random number distribution.

CONTENTS

Chapter 3

METHODOLOGY

1.1 BACKGROUND:

Due to rapid growth in demand of minerals, the mining industry is now being facing a great challenge for rapid production of different minerals to compete the market. For this mechanization of is obvious. Different types of mining machineries are now being used in mining industry. In the planning stage, the application of advanced computer techniques is being used. In an large opencast mines, the areas where the application of computer techniques are using are determination of production schedule, the breakdown maintenance schedule of the equipments for preventive maintenance and replacement policies, determination of optimal production schedule, optimum design of open pit, optimal blends and ore body modeling, selection of Machineries and matching factor with production. The present study is based on application of Monte-Carlo Simulation Technique on production optimization and simulation of break-down of mining machineries for their preventive maintenance for maintaining a steady-state production.

During production planning, it is required to have production target on a fixed time schedule, i.e. on yearly basis or monthly basis or on day to day basis. After having the production target it is very important to decide the requirement of exact number of machinery to achieve the target. Because of high rate of the Machineries (i.e. initial investments), considering their spare parts and high level of maintenance, profitability, suitability for the mines, feasibility study of the machines are very important to minimize their breakdown frequency. So, it will be helpful, if the selection of machineries is done in a mathematical manner using computer programming with the help of Monte-Carlo Simulation Technique. However this study is limited only in cost estimation of shovel-dumper transport system and the number of machineries best fit to the system from the available field data.

An important aspect of long-term production planning is maintaining a steady-state production with target achievement. For that which needed is subdivided the period into medium-term which is 1-5 years, provided that long-term production planning is generally 25-30 years. So, for the sub- divided period is to fix the rate of production from the mine. Calculation of requirement of machineries, plant, manpower etc, for highly mechanized mines so many machineries are used, like drill machine, shovel, dumper conveyor belt, dozer, primary crusher, electrical sub-station, primary and secondary crusher. Blasting process involves bulk explosive handling etc. So, without proper matching of all Machineries and related activities a steady-state production cannot be achievable. Sudden break down of any machinery may stop entire system.

1.1.1 An overview of Proposed Model

Production scheduling, along with production planning, provides projections of future mining progress and time requirements for the development and extraction of a resource. These schedules and plans are used by the management at a means of attaining the following objects they are

(1) Maintaining and maximizing this expected profit.

(2) Determining future investment in mining.

(3) Optimizing return on investment (R.O.I)

(4) Evaluating alternative investment.

(5) Conserving and developing owned recourses.

The first four objectives are related to mining cost, bolt capital and revenue requirements, and play an important role in production planning (Michail B. Kahle) and the fifth one is conservation and resource development. (Fred J. Scheaffer) which can be done by preventive maintenance from breakdown data analysis new technologies available from the market survey and calculation of their cost-effectiveness (Turkey aultis).

1.1.2 Long-Term Production Planning:

The long term production planning design is a major step in a planning, because it aims to maximize the net present value of the total profits from the production process while satisfying all the operational constraints, such as mining slope, grade blending, ore production, mining capacity, etc. During each scheduling period with a pre determined high degree of probability. Also Long-Term mine planning acts as a guide for the medium-term and short-term mine planning.

1.1.3 Medium-term/Intermediate-range planning mine plans

The duration of medium-term mine plan is in the range of 5-10 years period. This is further divided into 1-6 months of range for more detail scheduling.

The Goals; -

(1) Waste productions requirements.

(2) Obtaining optimum or near optimum cash flows within the total reserves as outlined in the long range plan.

(3) Maintain the required pit slopes. This planning technique allows the removal of material in large increases while maintain the required pit-slops and providing the operational and legal constraints.

(4) The mine management is also provided with sufficient time for analyzing critical requirements, especially equipment units with long-delivery times.

1.1.4 The short range mine planning:

The duration of this phase of the mine design is concerned with daily, weekly, monthly and yearly mine schedules and plans. The following are the activities associated with the short-term mine planning.

(1) Production schedules.

(2) Operating equipments.

(3) Material handling procedures.

The production scheduling is important to the overall mine design become of the substantial costs associated with labor, supplies, equipment which is affected by the production schedule.

The generalization of the production schedule is difficult. Most mines vary in size, mining methods, geometry and management philosophy. Consequently, scheduling procedures used for optimum results at one mine may be completely different from another. Some of the more universally accepted concepts used in many mining operations are discussed in the following sections. The productions schedule is a plan relating to production rate-the production rate is material per unit of time for an equipment unit or aeries of equipment unit

1.2 PRODUCTION SCHEDULE:

1.2.1 Introduction:

Production scheduling along with production planning, provides projections of future mining progress and time requirements for the development and extraction of a resource. These schedules and plans are used by management as means of attaining the following objections;-

(1) Maintaining or maximizing expected profit,

(2) Determining future investment in mining,

(3) Optimizing return on investment, (ROI)

(4) Evaluating alternative investments, and

(5) Conserving and developing owned resourced.

The first four goals are generally concerned with mining cost, both capital and operation requirements, and as such, play an important role a production planning. However, this chapter is concerned with the fifth management objective of resource development in order to conserve and perpetuate the corporate entity. The following discussion is based on the premise that detailed economic evaluations and market surveys have been performed and analyzed and that the results indicate a viable projects.

1.2.2 Relationship of Production Scheduling to Mine Design:

Mine Design

The development of a mine design for a long-range mine plan based on a mineralization inventory of the resource. This mineralization model is built from borehole data collected during exploration and development drilling programs and the geological interpretation of data. The major goal of this stage is to examine and evaluate the mineral deposit in sufficient detail to define economic tonnages and grades /quality of the resource, quantities of waste, and the geometry of the mine. These parameters are used to establish ore reserves, economic pit-limits, stripping ratio, and initial investment planning.

The second stage in the design of amine is intermediate- range planning. The intermediate-range plan established the five to ten- year resource and waste production requirement for obtaining optimum or near- optimum cash flows within the total reserves as outlined in the long-range plan. This planning technique allows the removal of material in large increments while maintaining the required pit slopes and providing for operational and legal constraints. Mine management is also providing with sufficient time for analyzing capital requirements, specifically equipment units with long delivery times.

The third stage in mine design is short-range mine planning. This phase of the mine design is concerned with daily, weekly, and yearly mine schedules and plant. These short-range mining activities are dependent on three basic activities;-

(1) Production schedules,

(2) Operating equipment, and

(3) Material handling procedures.

This chapter discusses the first activity, production schedules, and presents some of the methods and procedures used in production scheduling for various production rates.

Production Schedules:

Production scheduling is important to the overall mine design because of the substantial costs associated with labor, supplies, and equipment which are affected by the production schedule.

The generalization of production scheduling is difficult. Most mines vary in size, mining method, geometry, and management philosophy. Consequently, scheduling procedures used for optimum results at on mine may by completely different at another. Some of the more universally accepted concepts used in many mining operations are discussed in the following section.

The production schedule is a plan relating to (1 production rate and (2) operating layout. These factors establish the main criteria for the development of production schedule. The production rate determines the limits of production capacity for a production unity such as a shovel and a fleet of haulage trucks. A series of this production unit established the overall production of the mine .The operating layout established the physical constraints which will be encountered by the production unity. Time, a finite constraint, establishes the duration or length of the schedules.

Production rate; - The production rate is material per unit of time for the equipment unit or a series of equipment units. The material factor of the production rate can be described as follows.

(1) Metric tons (short tons) per hour, shift, day or year, and

(2) Cubic meter (cubic yards) per hour, shift, day or year.

Care must be used when describing these rates because of the major confusion associated with the time element. The confusion usually occurs because of the difference between an operating hour and a scheduled hour. Scheduled hour relates usually to the time paid the operator or time scheduled for the operator on equipment unit. An example of scheduled time would be 60 min to an hour or 8 hr per shift.

An operating hour usually refers to the production time of the production unit. An example of an operating hour would be 60 min (scheduled hour) minus normal operating delay time, such as fueling, lubrication, coffee break, etc.

The time factor of the production rate can also has described as

(1) Hours per shift.

(2) Shifts per day, and

(3) Operating equipment, and

(4) Material handling procedures.

(5) Day per year.

This chapter discusses the first activity, production schedules, and presents some of the methods and procedures used in production scheduling for various production rates.

These criteria are usually established by a management decision based on socio-economic conditions such as holiday or vacation schedules at other surrounding mines, labor contracts, and total plant utilization philosophies.

Operating layout; - The operating layout element of production scheduling is the establishment of the physical or operating constraints of the mine design. Some of the key factor that must be taken into account when developing an operating layout are;-

(1) Established pit operating production,

(2) Expected ore grades,

(3) Planned operating slopes,

(4) Designed haul roads,

(5) Planned dump development,

(6) Planned backfilling and reclamation sequences,

(7) Designed surface and ground-water controls,

(8) Required equipment size and maneuverability, and

(9) Planned bench development.

The main objective of operating layout in production scheduling is to determine how far in advance a certain resource must be stripped to maintain the required production rate and resource grade or quality.

1.3 OBJECTIVE OF THE STUDY:

The objective of the study is restricted in mine production optimization as selection of machinery using Monte-Carlo simulation technique and break down analysis of the open cast mining Machineries to reduce and control the break down for maintaining a steady-state production from large mechanized opencast mines.

1.4 SCOPE OF WORK:

In order to accomplish the above stated objectives, the scope of work divided into following tasks.

1) Literature Review

An extensive literature review was carried out on the application of computer techniques to solve the mine production scheduling problem and production optimization problems. An extensive use of mathematical approaches to solve the different optimization problems are carried out such as Linear programming problem, Post optimal analysis, Sequencing Problem, Dynamic programming , Investment analysis and break-even analysis, Queuing Theory, Simulation, Network Scheduling by *PERT/CPM* method etc.

2) Mine Visit and data collection

   Mine visit was carried out in different mechanized open cast and underground such as OCL- Langiberna, Orissa; Barsua Iron Ore Mines, Aryan Co. Pvt. Ltd.; Kiriburu and Megataburu Iron Ore Mines; MCL Mines, Orient 3; and Basundhara mines. Different data were collected regarding cost of machineries, Make, model, operating cost, break down data, availability,

3) Development of frame work for modeling and Simulation Algorithm

   In this study, modeling and simulation algorithm was used based on break down data of the different machineries generating uniformly distribute random numbers and also in same way availability of the dumpers and shovel and their service facility in a shovel-dumper combination transport system to maintain a steady state production. For this purpose ‘C’ program has been developed.

1.5 SIGNIFICANCE OF THE THESIS

The contribution of this thesis is twofold: i) Simulation of machineries in a shovel dumper transport combination for cost optimization of initial investment (discussed in chapter 3), and ii) Simulation of breakdown data analysis of different opencast machineries (discussed in chapter 4). Most often simulation technique is neglected during selection of machineries and also breakdown of any machinery imparts entire stop of the system. This study must be helpful to the mining engineers as well as management to decide while selection of machineries and for preventive maintenance formaintaining a steady-state production in a better way. It is beneficial in many fonts as compared to other optimization algorithm.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

An extensive literature survey was done in order to approaches adapted by the researches in the past. The literatures reviewed in the present research may be categorized according to their approaches to solve mine production scheduling problem using mathematical models as deterministic models, which always yields the same output for fixed input values, but in this research it is shown either in case of breakdown of machineries which is uncertain in nature, so uniformly random numbers are created as input and the result or outputs are categorized in such a manner that in future it can be sort out from their particular category before further sudden breakdown. Thus it is minimized to maintain a steady state production. Also in case of service facility of a shovel and arrival of a dumper is uncertain in nature, so uniformly distributed random numbers are generated as input to the models. Thus output is minimization of waiting time of both shovel and dumper to reduce the cost of investment of the machineries. It optimizes the net present value of the profits over the life of the mine.

2.2 DETERMINISTIC MODELS OF MINE PRODUCTION SCHEDULING:

Using of different mathematical models for mine production scheduling is extensively surveyed. The introduction of the concept of linear programming for optimization of mine production scheduling was made by Johnson (1969). He used linear programming to determine a feasible extraction sequence which ultimately maximized the total profits over the planning horizon. A dynamic cut-off grade strategy was applied to determinate between ore and waste in a mineral deposit and this cut-off change with time. The scheduling problem was formulated as a large scale linear programming problem considering governing constraints of the system and further by applying decomposition principle, the problem was decomposed into simple linear programming problem, called the master problem and set of sub-problem was relatively simple.

Gershon (1982) also applied the linear programming approach to schedule mining operation in a optical manner. He presented cases in which linear programming was applied in three different mines which include a copper, a coal and a limestone mine. He developed and presented a mine scheduling optimization (MSO) approach. This system, which optimizes the net present value of the profit over the life of mine, considers multiple pits, poly-metallic ores ore handling and processing facilities, environmental limitation and product sales[1,3]. MSO represents advances in the state-of-the-art of linear programming applications to mine scheduling in five areas such as scope and generality of the problem addressed, model formulation, computational requirements and the long-term and short term interfaces. Generalized in its organization, this approach was applicable to a wide variety of mining operations. Wilke et al. (1984) employed a simulation algorithm in conjunction with linear programming to determine the long-term and medium-term production schedules. They used simulation for handling geometric and equipment restrictions, and linear programming for determining optimum ore and waste handling over time horizon [5,11].

K. C. Brahma, B. K. Pal & C. Das (2008) attempt to throw some light on mine automation using the concept of Petri Nets. The drilling operation in an opencast mine with double rod drilling provision has been considered for analysis and has been simulated [23,27]. They shows Petri Net based modeling of drilling operation is a simple and effective method that can provide an insight to the academicians and mine managers to further develop a more refined and realistic time and cost estimates for complex opencast mine projects. The Petri Nets can be applied for automation in mining technology in an environment friendly and safe manner so that zero accident potential (ZAP) can be achieved. Temporary machine failures can be averted with better simulation which can be updated time and again reducing the break down hours to minimum [12,35].

T. Cichon (1998) developed computer techniques and resultant increased speed and accuracy of calculation carried out, easy graphic representation of design and its duplication, quick creation and processing of databases and also, their searching, further treatment of graphic files, possibility to create spatial model of design facility, its visualization, archive of data, brought about an interest in aiding of mine planning by specialized computer programs. Computer software is used as micro station, Intergraph, I/Mine modeler, Intrasoft MX Foundation (MOSS), Data mine Studio, Auto CAD or commonly used MS Office package [24,25].

U. A. Dzharlkaganov, D. G. Bukeikhanov & M. Zh. Zhanasov (2004) presented of automated forming of perspective and current plans of mining operations development when open mining of complex structural multi-components iron-ore and poly-metallic deposits. It includes two programming functional complexes (modules): optimizing and interactive [13, 22].

It shows joint using of two modules with different ideology and principles of operation in one system of computer aided design and planning of mining operations at opencasts allows substantially increasing quality and decreasing duration of decision making [19, 20].

Also by using the first module of optimization calculations and construction of contours of mining operations in package regime we receive the most priority directions of moving of mining operations by working levels. It allows substantially decreasing time of a search of optimal contours of mining operations up to the end of planned period [14, 28].

The second module is used for taking final decision in interactive regime and allows more adequate taking into account possible complex situations. It may be used in addition to operations of the first module or as independent apparatus for current and timely planning of mining operations [15, 26].

For taking correct decision it is important to ensure a forenamed subsystems with reliable information about interaction of parameters and indexes of operation of opencast in different mining-technical and technological conditions with the help of spatial recognizing algorithm and formulae [18, 29].

Using of different mathematical models for mine production scheduling is extensively surveyed. The introduction of the concept of linear programming for optimization of mine production scheduling was made and elaborated [9, 10]. They used linear programming to determine a feasible extraction sequence which ultimately maximized the total profits over the planning horizon.

A dynamic cut-off grade strategy was applied to determinate between ore and waste in a mineral deposit and this cut-off change with time. The scheduling problem was formulated as a large scale linear programming problem considering governing constraints of the system and further by applying decomposition principle, the problem was decomposed into simple linear programming problem, called the master problem and set of sub-problem was relatively simple.

The drilling operation in an opencast mine with double rod drilling provision has been considered for analysis and has been simulated [2, 37]. Computer techniques were applied for design of dragline operation and its graphic representation for quick processing of databases was developed [6, 16].

Also by using the first module of optimization calculations and construction of contours of mining operations in package regime we receive the most priority directions of moving of mining operations by working levels. It allows substantially decreasing time of a search of optimal contours of mining operations up to the end of planned period [4, 36].

The second module is used for taking final decision in interactive regime and allows more adequate taking into account possible complex situations. It may be used in addition to operations of the first module or as independent apparatus for current and timely planning of mining operations [8, 17].

For taking correct decision it is important to ensure a forenamed subsystems with reliable information about interaction of parameters and indexes of operation of opencast in different mining-technical and technological conditions with the help of spatial recognizing algorithm and formulae [7, 21].

Chapter 3

METHODOLOGY

3.1 INTRODUCTION:

After mining company has got the lease of a mineral deposit, the problem is then how to mine and process that deposit the best way. The principle problem facing managers or engineers who must decide on mine plant site, equipment selection and long range scheduling is how one can optimize a property not only in terms of efficiency but also as to project duration. For faster rate of production mechanization at a high degree is obvious. With the advanced technology different types of mechanization such as shovel, dumper, dozer, drill machine etc. Use of more machineries leads to more complexity in operation and as result it is very difficult to make the proper matching of those equipments. These Machineries are very costly. So unless they are properly matched reduction in production cost is very difficult. Increase in idle times of machineries leads to increase in production cost. In order reduce the idle time or waiting time. The number of machineries may be increased. Due to higher cost of machineries more investment is needed which ultimately contribute in higher production cost. So, unless you getting a perfect matching with optimum number of equipments reduction in production cost is impossible. So, it is needed to analyses the operations of equipments considering their break down periods, repairing, maintenance of preventive maintenance, availability of spare-parts, efficiencies of operators and management philosophy etc. This study is based on use Monte – Carlo technique in operation of shovel- dumper combination.

The field of modeling and simulation is as diverse as the concern of the man. Every discipline has developed, or is developing, its own models and its own approach and tools for studying these models.

The necessary of simulation and modeling relies on the same reasoning that determined that we should have acquired at least some grounding in mathematics. Nobody questions the role of arithmetic in the sciences, engineering and management. Arithmetic is all pervasive, yet it is a mathematical discipline having its own axioms and logical structure. Its content is not specific to any other discipline but is directly applicable to them all.

The practice of modeling and simulation too is all pervasive. However, it has its own concepts of modeling description, simplification, validation simulation and exploration, which are not specific to any particular discipline. These statements are agreed to by all.

3.2 SYSTEM MODELING CONCEPT:

This is the key concept that underlies the framework and methodology for modeling and simulation. The most basic concept is that of mathematical system theory. Which was first developed in 1960s, this theory provides a fundamental, rigorous mathematical formalism for representing dynamical system of mines loading system of shovel dumper combination and various machineries breakdown statistics and their performances. There are two main, orthogonal, aspects to the theory [30, 31].

1) Levels of system specification – These are the levels at which we can describe how system behave and the mechanism that make the framework the way they do.
2) System specification formalism- These are the systems of modeling style, such continuous or discrete, that modelers can use to build system models.

The theory is quite intuitive, it does present an abstract way of thinking about the world that we will probably unfamiliar.

3.3 SYSTEM SPECIFICATION FORMALISM:

System theory distinguishes between systems structure which is the inner constitution of a system and behavior which is its outer manifestation. Viewed as a black board system, the external behavior of a system is the relationship it imposes between its input time histories and output time histories. The system input /output behavior consist of the data of the pairs of the data records which is input time segments paired with output time segments and gathered from a real system or model . The internal structure of a system includes its state and state transition mechanism (dictating how inputs transform current states into successor states) as well as the state-to-output mapping. Knowing the system structure which allows us to deduce (analyze and simulate) its behavior. Usually the other direction (interfering structure from behavior) is not univalent- indeed, discovering a valid representation of an observed behavior is one of the key concern of the modeling and simulation enterprise [32, 33].

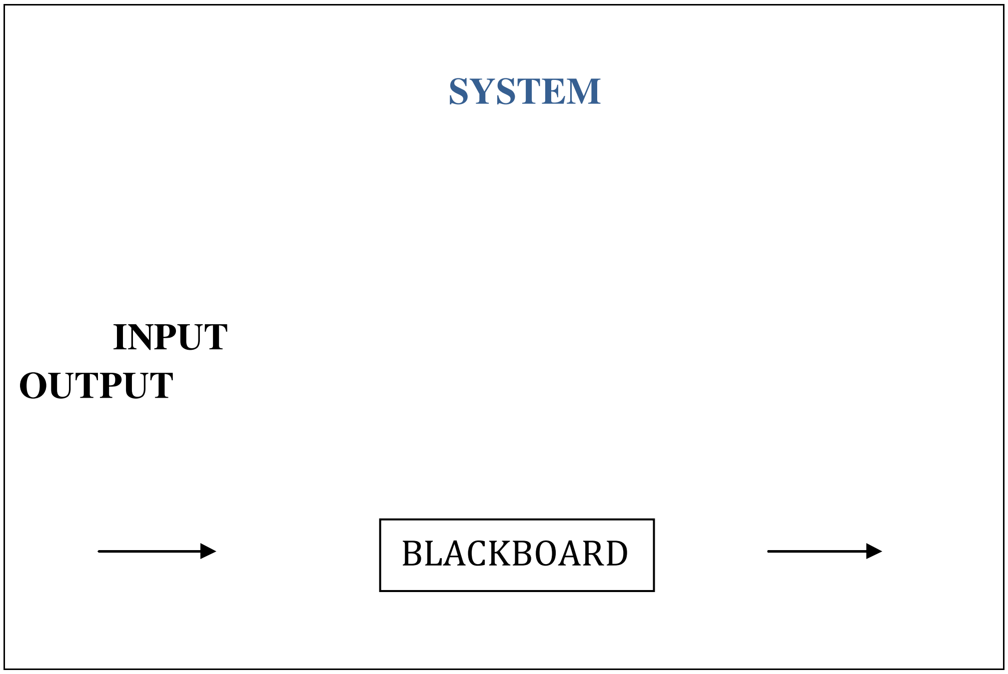

Figure 3.1: Basic system concepts

An important structure concept is that of decomposition , namely, how a system may be broken down into component system, a second system is that of composition, i.e. how component system may be coupled together to form a larger system. System theory is closed under composition in that the structure and behavior of a composition of a system can be expressed in the original system theory terms. The ability to continue to compose larger and larger

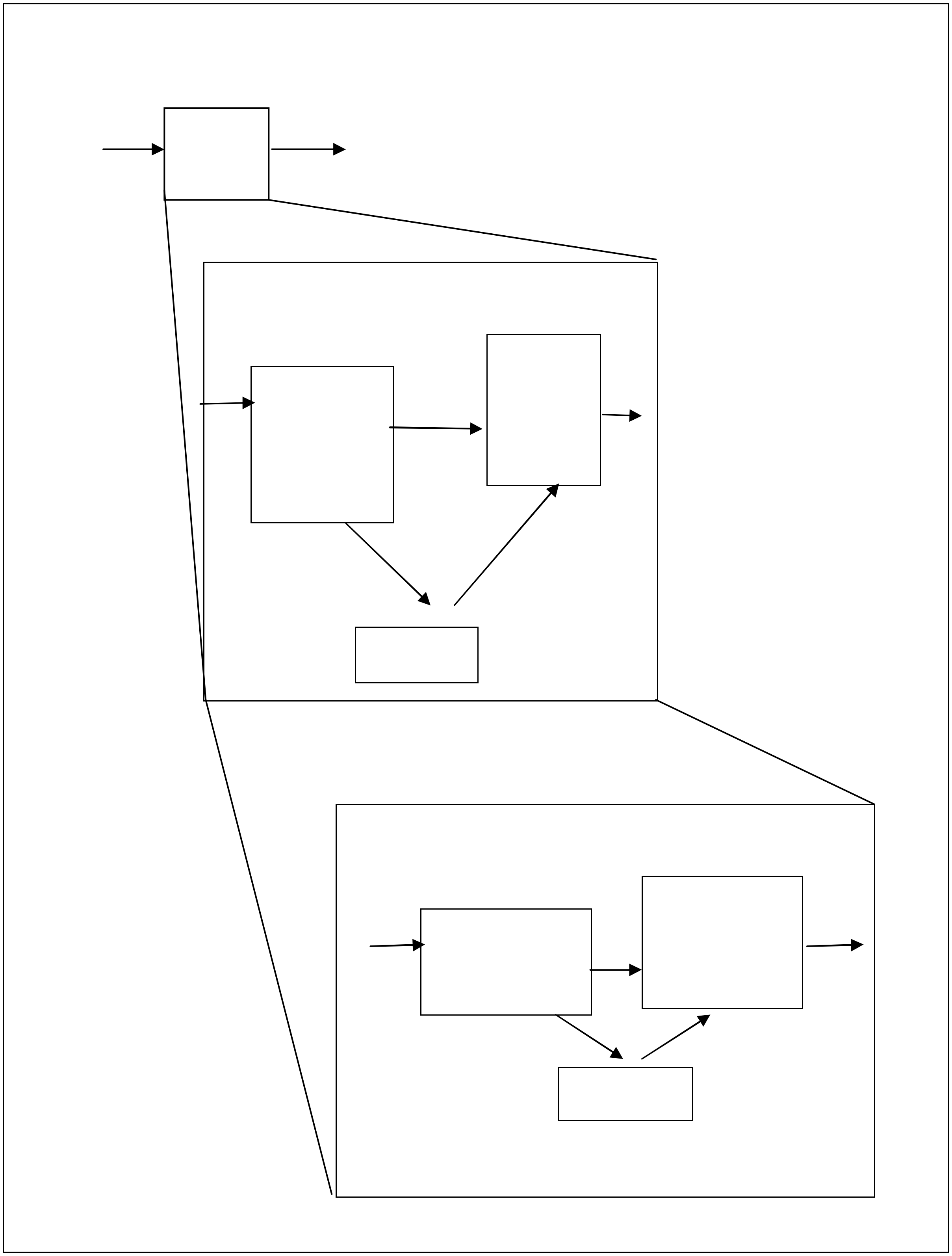

Fig 3.2: Hierarchical system decomposition

systems from previously constructed components leads to hierarchical construction. Closer under composition guarantees that such a composition results in a system, called its resultant, with well defined structure and behavior. Modular systems have recognized input and output ports through which all interaction with the environment occurs. They can be coupled together by coupling output ports into input ports and can have hierarchical structure in which component system are coupled together.

The different between decomposed system and undecomposed system provides the first introduction to levels of system specification. The former are at a higher levels of specification than the latter since they provide more information about the stricter of the system.

3.4 RELATION TO OBJECT ORIENTATION:

Models developed in a system theory paradigm bear a resemblance to concept of object oriented programming. Both objects and system models share a concept of internal state. Mathematical system is formal structure that operates on a time base; whereas programming objects typically do not have an associated temporal semantics. Objects in typical object-oriented paradigms are not hierarchical or modular in the sense just describes. The coupling concept in modular system provides a level of delayed binding – a system model can place a value on one of its ports, but the actual destination of this output is not determined until the model becomes a component in a larger system and a coupling scheme is specified. It can therefore

a) Be developed and tested as a stand-alone unit.
b) Be placed in a model repository and reactivated at will , and
c) Be reused in any applications context in which its behavior is appropriate and coupling to other components makes sense.

Although coupling establishes output-to-input pathways, the system modeler is completely free to specify how data flows along such channels. Information flow is one of many interactions that may be represented. Other interaction includes physical forces and fields, material flows, monetary flows, and social transactions. The system concept is broad enough to include the representation of any of these and supports the development of Modeling & Simulation environments that can include many within the same large scale model.

Although system models have formal temporal and coupling features not shared by coupling features of conventional objects, object orientation does provide a supporting computational mechanism for system modeling. Indeed there have been many object oriented implementations of hierarchical modular modeling systems. These demonstrate that object-oriented paradigms, particularly for distributed computing, can serve as a strong foundation to implement the modular system paradigm [34].

3.5 SYSTEM FORMALISM EVALUATION:

As in many situations, portraying the evaluation of an idea may help understand the complexities as they develop. The basic systems modeling formalism as they were presented in the TMS76. This was first approaches to modeling as system specification formalism. This Is shorthand means of delineating a particular system within a sub class of all systems. The traditional differential equation systems, having continuous states and continuous time, were formulated as the class of differential equation system specification (DESS). Also system that operated on a discrete time base such as automata were formulated as the class of Discrete Time System Specification (DTSS). In each of these cases, mathematical representation had proceeded their computerized incarnations (Newton-Leibnitz).

However, the reverse was true for the third class, The Discrete Event System Specification (DEVS). Discrete event models were largely prisoners of their simulation language implementations or algorithmic code expressions. Indeed there was a prevalent belief that discrete event “world views” constituted new mutant forms of simulation, unrelated to the traditional mainstream paradigms. Fortunately, that situation has begun to change as the benefits of abstractions in control and design became clear. Witness the variety of discrete event dynamic system formalisms that have emerged.

While each one – examples are petri-nets, minimax algebra, and GSMP (Generalized semi-Markov processes)- has its application area, none were developed deliberately as subclasses of the system theory formalism. Thus to include such a formalism into an organized system-theory-based frame-work requires “embedding” it into DEVS.

“Embedding”. It indicates subclass relationships; for example they suggest that DTSS is subclass of DEVS. However, it is not literally true that any discrete time system is also discrete event system (their time bases are distinct, for example). So, we need a concept of simulation that allows us to say when one system can do the essential work of another. One formalism can be embedded in another if any system in the first can be simulated by some system in the second. Actually, more than one such relationship, or morphism may be useful, since, as already mentioned, there are various levels of structure and behavior at which equivalence of the system could be required.

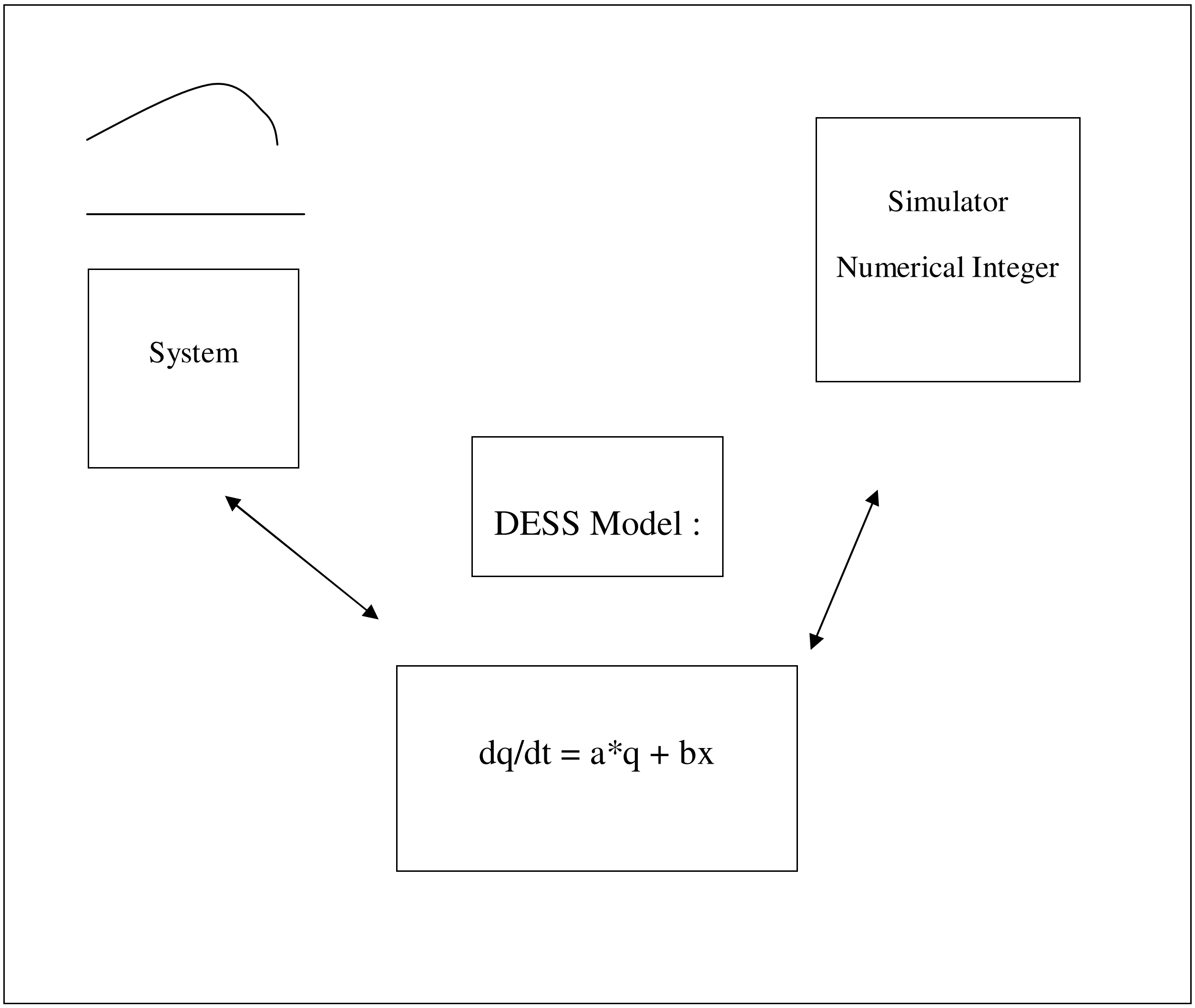

Fig3.3: System Specification Formalism

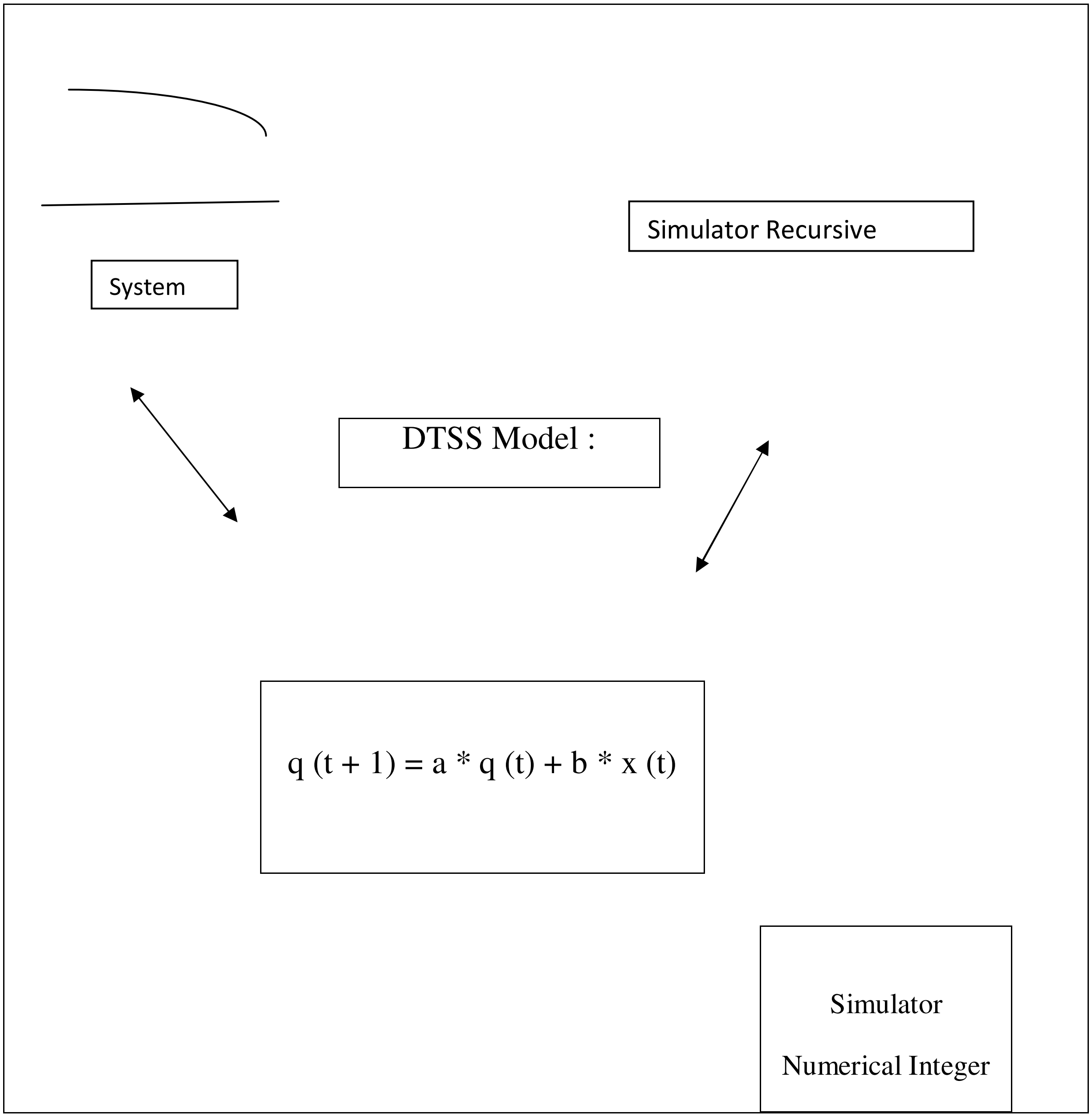

Fig3.4: System Specification Formalism

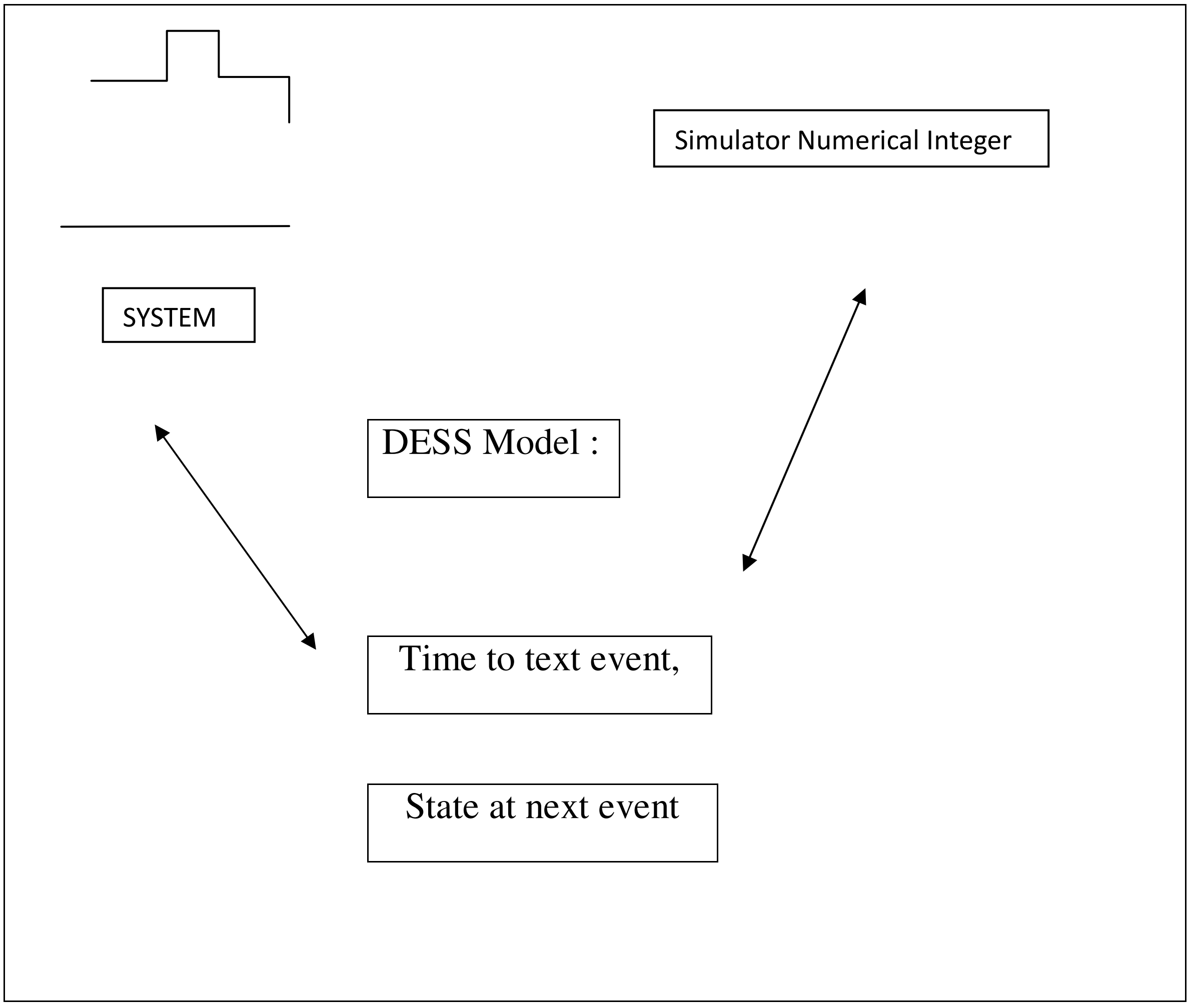

Fig3.5: System Specification Formalism

As a case in point any DTSS could be simulated a DEVS by constraining in time advance to be constant. However, this is not as useful as it could be until we can see how it applies to decomposed systems. Until that is true, we either must reconstitute a decomposed discrete time system to its resultant before representing it as a DEVS but we cannot network the DEVS together to simulate the resultant.

3.6 COMBINATION OF CONTINUOUS AND DISCRETE FORMALISMS:

Skipping many years of accumulating developments, the next major advance in system formalisms was the combination of discrete events and differential equation formalism into one, the DEV&DESS. As shown in Fig: 4

This formalism subsumes both the DESS and the DEVS (hence also the DTSS) and thus supports the development of coupled system whose components are expressed in any of the basic formalisms. Such multi-formalism modeling capability is important since the world does not usually lend itself to using one form of abstraction at a time. For example, a chemical factory is designed with discrete event formalisms. Also DEV & DESS were closed under coupling and in order to do so, had to deal with the pairs of input-output interfaces between the different types of systems. Closure under coupling also required that the DEV &DESS formalism provide a means to specify components with intermingled discrete and continuous expressions. Finally, simulator algorithms (so called abstract simulators) had to be provided to establish that the new formalism could be implemented in computational form.

3.7 QUANTIZED SYSTEM:

Since parallel and distributed simulation is fast becoming the dominant form of model execution, and discrete event concepts best fit with this technology, our focus is on a concept called the DEV bus. This concept, introduced in 1996 concerns the use of DEVS models as "wrappers" to enable a variety of models to interoperate into a networked simulation. It is particularly germane to the high level architecture defined by United States Department of Defense. One way of looking at this idea is that we want to embed any formalism, including, for example, the DEV & DESS, into DEVS. Another way is to introduce a new class of systems, called quantized system, as illustrated in Fig: 6. In such systems, both the input and output are quantized. As an example, an analog-to-digital converter does such quantization by mapping a

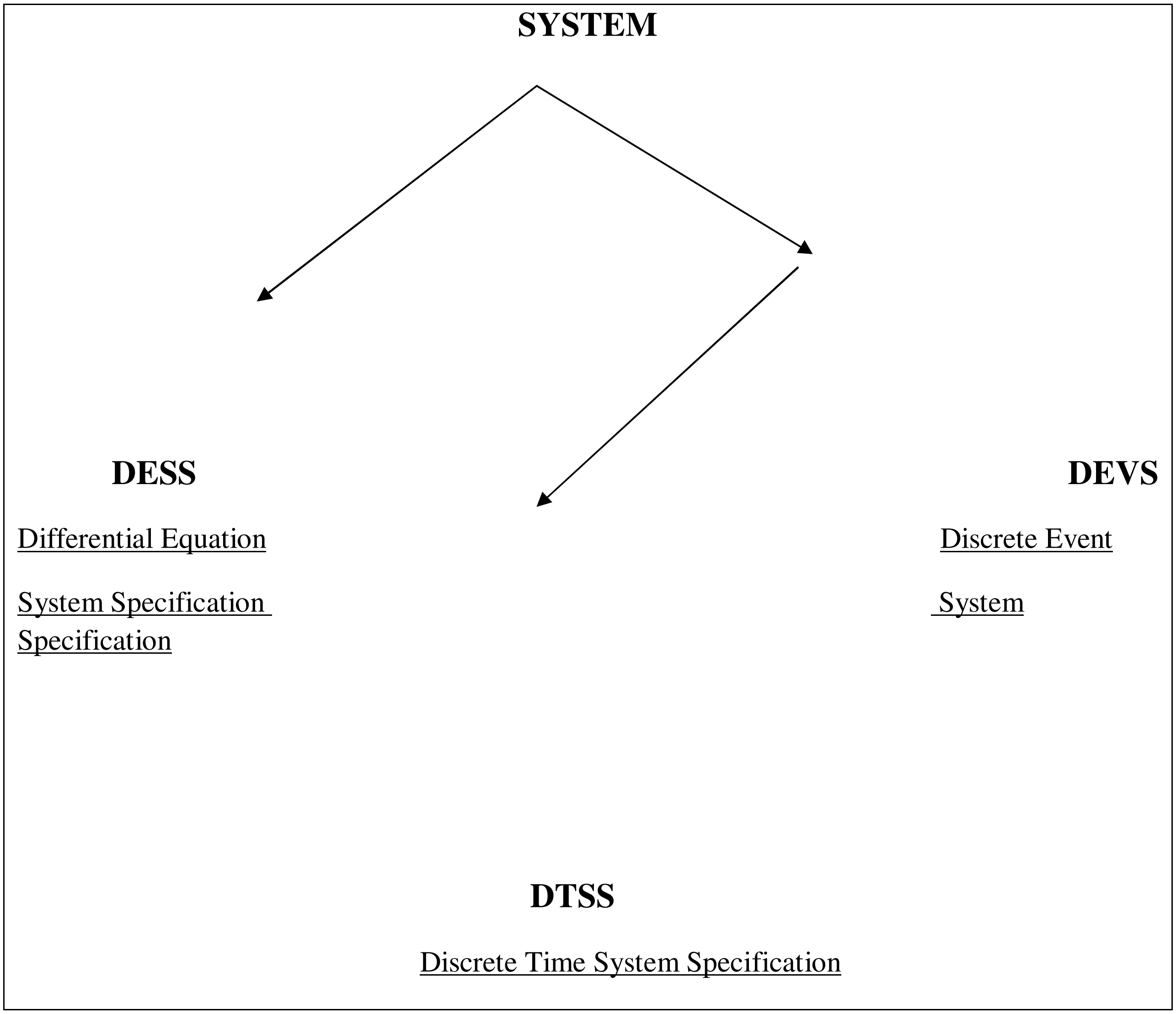

Fig: 3.6 The Dynamics of Basic System Classes

real number into a finite stringed of digits. In general, quantization forms equivalence classes of outputs that then become indistinguishable for downstream input receivers, requiring less data network bandwidth, but also possibly incurring error.

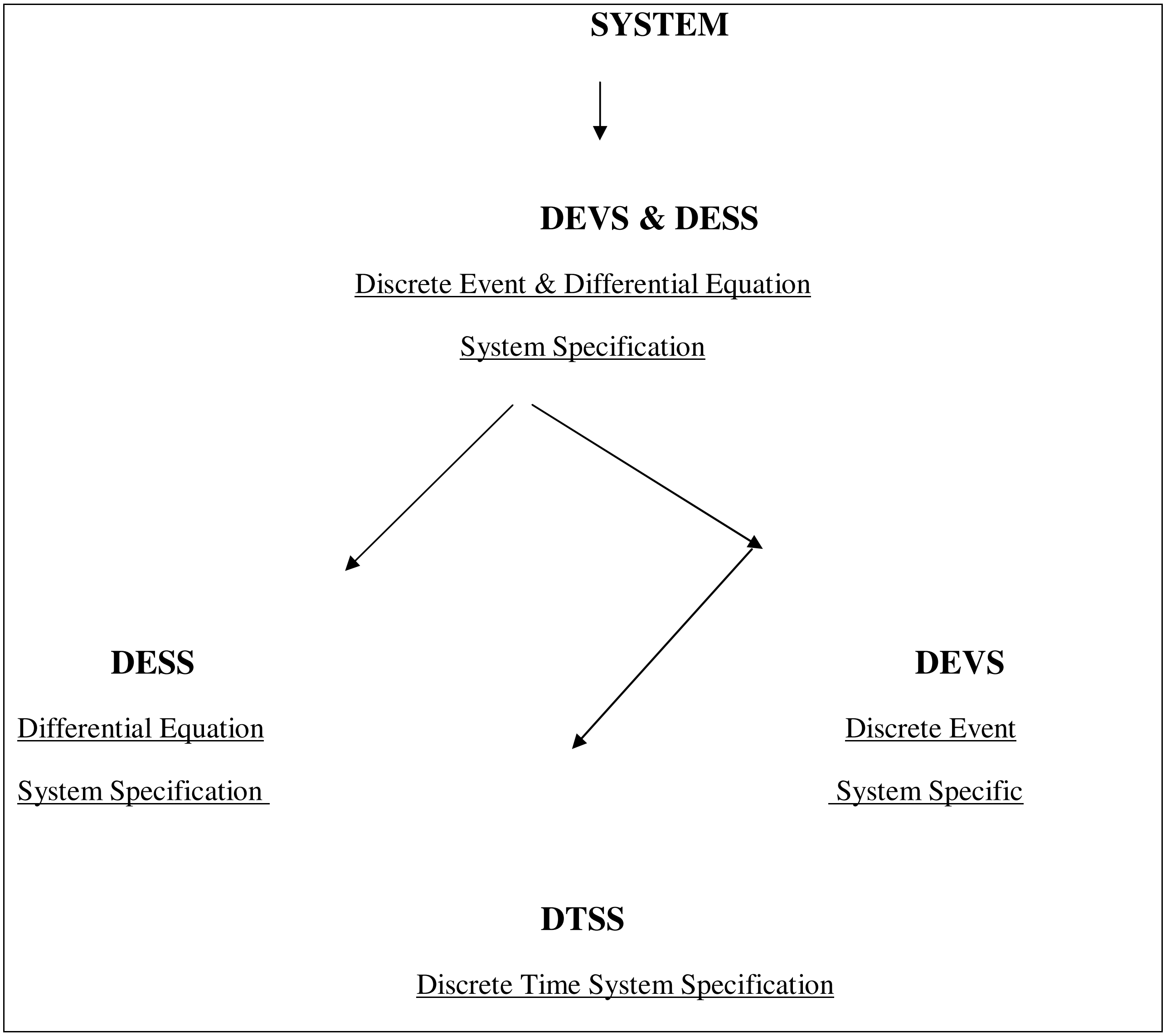

Fig: 3.7 Introducing the DEV & DESS Formalism

3.8 EXTENSION OF DEVS:

Various extensions of DEVS have been developed as illustrated in Fig: 7. These developments expand the classes of system models that can be represented in DEVS, and hence, integrated within both the DEVS bus and the parent systems theory formalism.

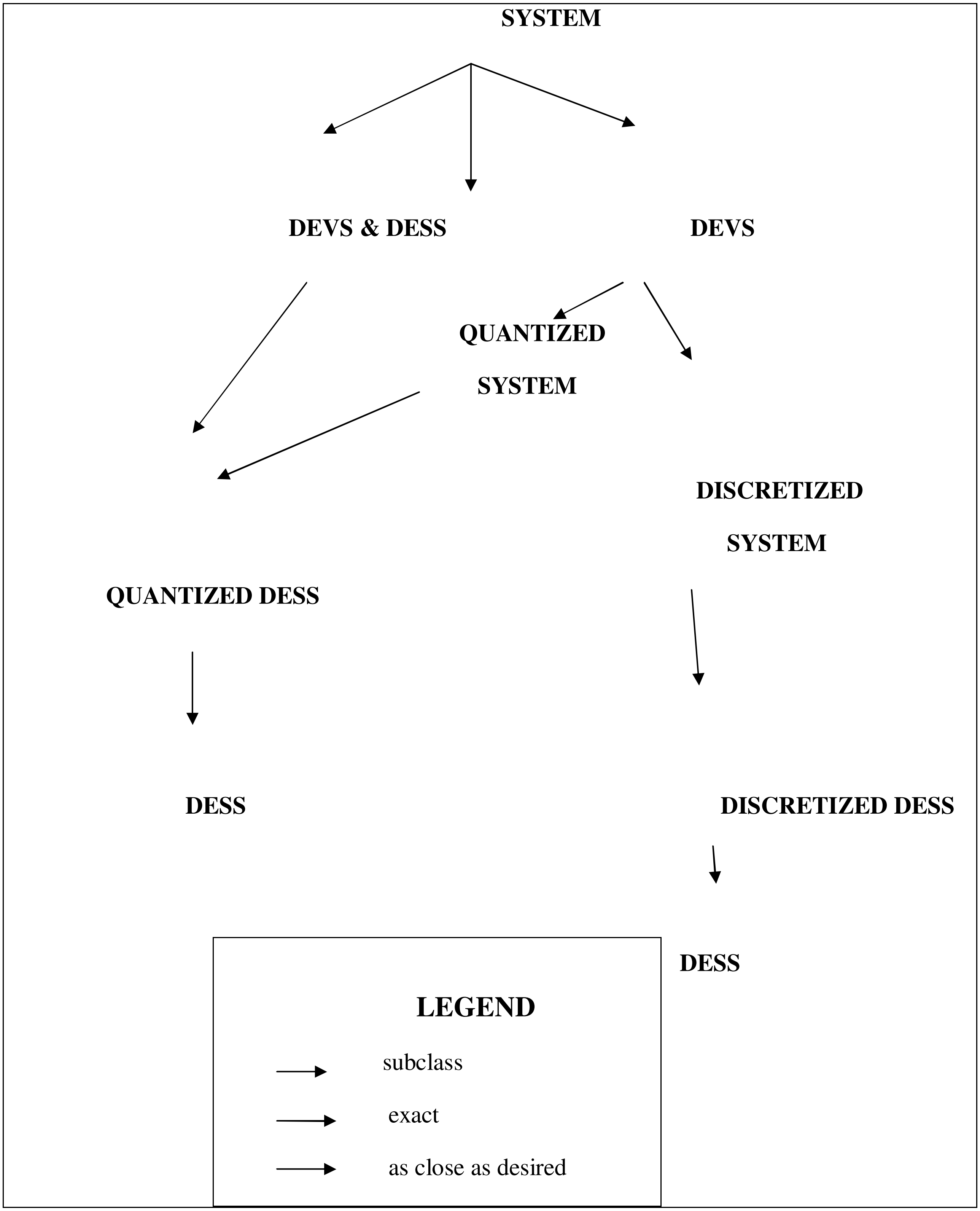

Fig 3.8: Introducing quantized system

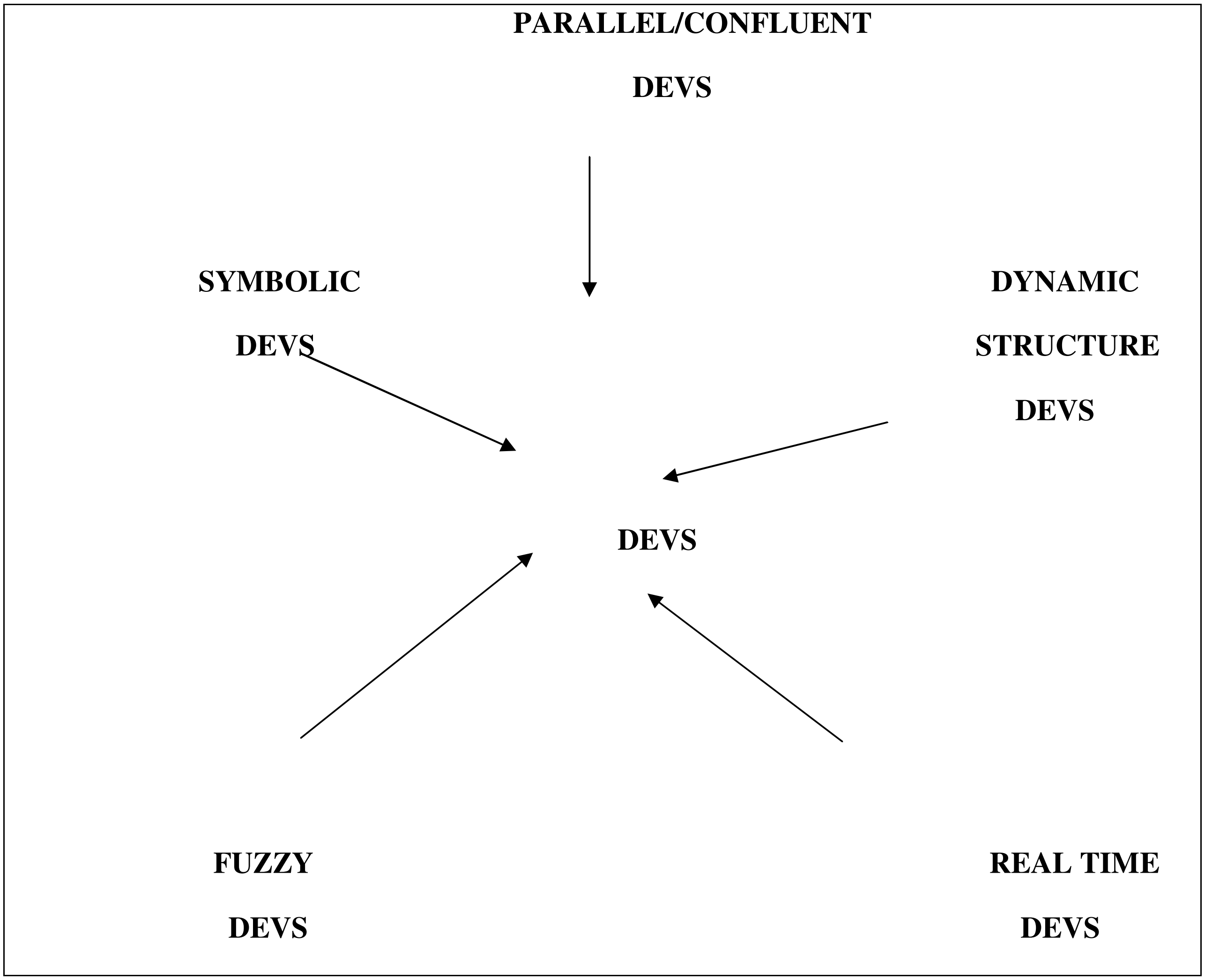

Fig 3.9: Extension of DEVS formalism

These developments lend credence to the claim that DEVS is a promising computational basis for analysis and design of systems, particularly when simulation is the ultimate environment for development and testing. The claim

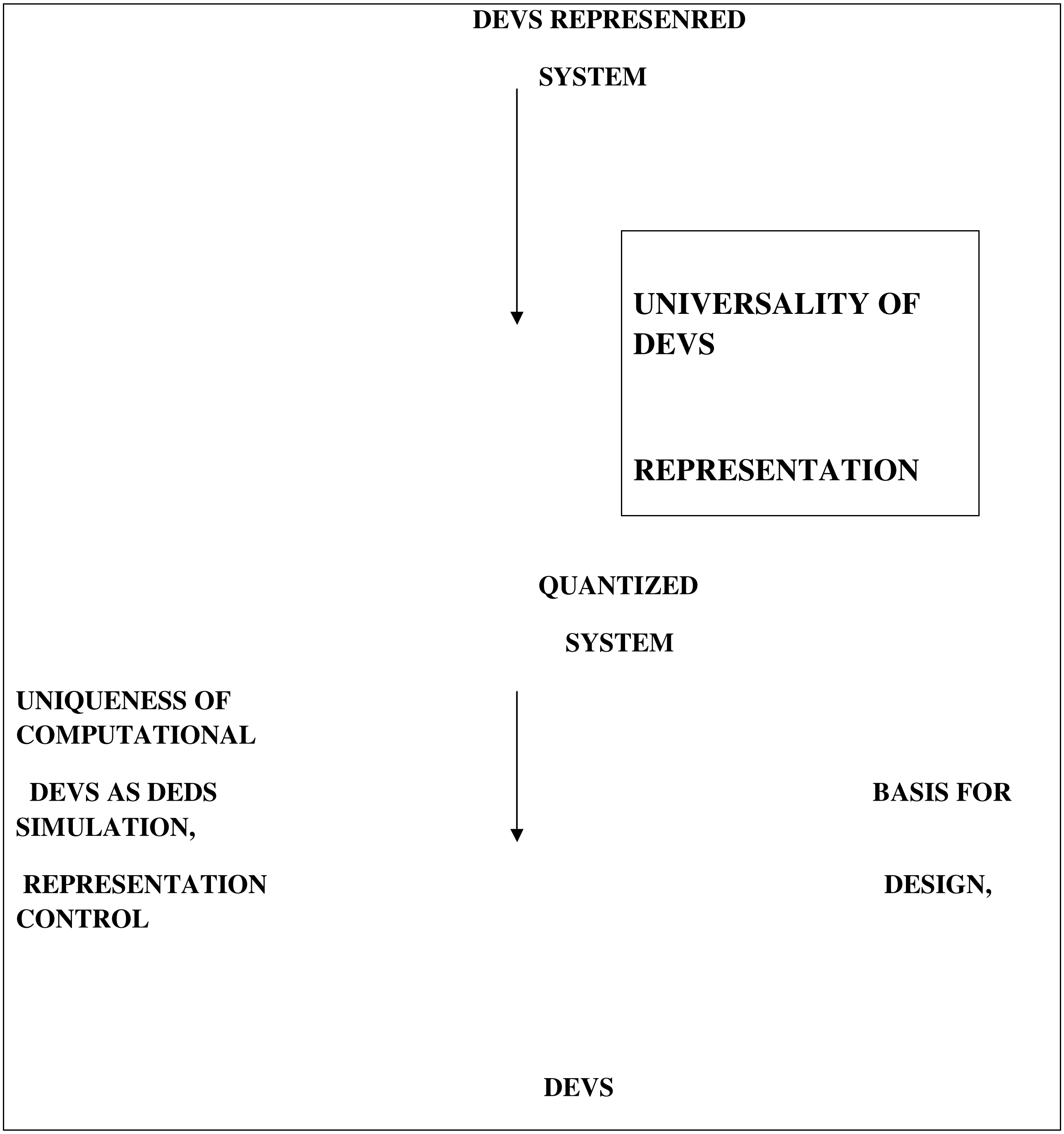

Fig 3.10: DEVS as a Computational basis for Simulation, Design and Control.

rests on the universality of the DEVS representation, namely the ability of DEVS bus to support the basic system formalism. DEVS is the unique form of representation that underlies any system with discrete event behavior. This uniqueness claim of DEVS, offers the promise that the profusion of discrete event formalisms under development for control and management of systems can be embedded as sub formalisms of DEVS in the DEVS bus and thus made accessible in an integrated distributed simulation environment.

3.9 LEVELS OF SYSTEM KNOWLEDGE:

The system specification hierarchy is the basis for a frame work for M & S which sets forth the fundamental entities and relationships in the M & S enterprise. The hierarchy is first presented in an informal manner and later, in its full mathematical rigor. This presentation is a review of George Klir's system framework.

Table 1 identifies four basic levels of knowledge about a system recognized by Klir. At each level we know some important things about a system that we did not know at lower levels. At the lowest level, the source level identifies a portion of the real world that we wish to model and the means by which we are going to observe it. As the next level, the data level is a data base of measurements and observations made for the source system. When we get to level 2, we have ability to recreate this data using a more compact representation, such as a formula. Since, typically, there are many formulae or other means to generate the same data, the generative level, or particular means or formula we have settled on, constitutes knowledge we did not have at the data system level. About the models in the context of simulation studies they are usually referring to the concepts identified at this level. That is, to them a model means a program to generate data. At the last level, the structural level, we have a specific kind of generative system. In other words, we know how to generate the data observed at the level 1 in a more specific manner-in terms component system that are interconnected together and whose interaction accounts for the observation made. Systems are often referring to this level of knowledge. The whole is the sum (or as some times claimed, more or less than the sum) of its part. The term "subsystem" is also use for these parts, and then they call component systems (and reserve the subsystem for another meaning).

Klir's terms are by no means universally known, understood, or accepted in the M & S community. However, his frame work is a useful starting point since it provides a unified perspective on what are usually considered to be distinct concepts. From this perspective, there are only three basic kinds of problems dealing with systems and they involve moving between the levels of system knowledge (table-2). In systems analysis, we are trying to understand the behavior of an existing or hypothetical system based on its known structure. System inference is done when do not know what this structure is-so we try to guess this structure from observation that we can make. Finally, in system design, we are investigating the alternative structures for a completely new system or the design of an existing one.

The central idea is that when we move to a lower level, we do not generate any really new knowledge-we are only making explicit what is implicit in the description we already have. Making something explicit can lead to insight, but it is a form of new knowledge, but Klir is considering this kind of subjective (or modeler-dependent) knowledge. In this M & S context, one major form of systems analysis is computer simulations which generate data under the instructions provided by a model. Although no new knowledge is generated, interesting properties may come to light of which we were not aware before the analysis. On the other hand, system inference, and system design are problems that involve climbing up the levels. In both cases, we have a low level system description and wish to come up with an equivalent higher level one. For system interference, the lower level system is typically at the data system level, being data that we have observed from some existing source system. We are trying to find a generative system, or even a structure system, that can recreate the observed data. In the M & S context, this is usually called model construction. In the case of system design, the source system typically does not yet exist and our objective is to build one that has a desired functionality. By functionality we mean that we want the system to do; typically, we want to come up with a structure system, whose components are technological, i.e., can be obtained off-the-shelf, or built from scratch from existing technologies. When these components are interconnected, as specified by a structure system coupling relation, the result should be a real system that behaves as desired.

It is very interesting that the process called reverse engineering has elements of both interface and design. To reverse engineering an existing system, such as was done in the case of the cloning of IBM compatible PCs, an extensive set of observations is first made. From these observations, the behavior of the system is inferred and an alternative structure to realize this behavior is designed-thus bypassing patent rights to the original system design.

Table3.1: Levels of System Knowledge

Level	Name	What we know at this Level
0	Source	What variable to measure and how to observe them
1	Data	Data collected from a source system
2	Generative	Means to generate data in a data system
3	Structure	Components (at lower levels) coupled together to form a generative system

3.10 INTRODUCTION TO THE HIERARCHI OF SYSTEM SPECIFICATION:

At about the same time (Klir 1970) he introduced epistemological (knowledge) levels, TMS76 formulated a similar hierarchy that is more oriented toward the M & S context. This framework employs a general concept of dynamical system and identifies useful ways in which such a system can be specified. These ways of describing a system can be ordered in levels as in table 3.

Table 3.2: Fundamental Systems Problems

System Problems	**Does source of the data exist? We are trying to learn about it.**	**Which levels transition is involved**
System analysis	The system being analyzed may exist or may be planned. In either case we are trying to understand its behavioral characteristics.	Moving from higher to lower levels, e.g. using generative information to generate the data in a data system.
System inference	The system exists. We are trying to infer how it works from observations of its behavior.	Moving from lower to higher levels, e.g., having data, finding a means to generate.
System design	The system being designed does not yet exist in the form that is being completed. We are trying to come up with a good design for it.	Moving from to lower levels, e.g., having a means to generate observed data, synthesizing it with compo-nent taken off the shelf.

3.11 SIMULATION

Simulation is a numerical technique for conducting experiments that involves certain types of mathematical and logical relationship necessary to describe the behavior and structure of a complex real world system over extended period time.

According to Shannon "Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior (within the limits imposed by a criterion or a set of criteria) for the operation of the system".

Using Simulation, an analyst can introduce the constants and variables related to the problem, set up the possible courses of action and establish criteria which act as measures of effectiveness.

Table 3.3: System Specification Hierarchy

Levels	Specification Name	Correspondence to Klir's	What we know at this level
0	Observation Frame	Source System	How to stimulate the system with inputs; What variables to measure and how to observe them over a time base;
1	I/O behavior	Data System	Time index data collected from a source system; consist of input/output pairs.
2	I/O function	--	Knowledge of initial state; given an initial state, every input stimulus produces a unique output.
3	State Transition	Generative System	How states are affected by inputs; given a state and what is the state after the input stimulus is over; what output vent is generated by a state.
4	Coupled Component	Structure System	Components and how they are coupled together. The components can be specified at lower levels or can even be structure systems themselves-leading to hierarchical structure.

3.12 REASONS FOR ADOPTING SIMULATION:

a) It is an appropriate tool for solving a business problem when experimenting on the real system would be too expensive.

b) It is a desirable tool when a mathematical model is too complex to solve and is beyond the capacity of available personnel. And is not detailed enough to provide information on all important decision variables.

c) It may be the only method available, because it is difficult to observe the actual reality.

d) Without appropriate assumption, it is impossible to develop a mathematical solution.

e) It may be too expensive to actually observe system.

f) There may not be sufficient time to allow the system to operate for a very long time.

g) It provides trial and error movements towards the optical solution. The decision maker selects an alternative, experience the effect of the selection, and then improves the selection.

3.13 TRANSPORT SYSTEM:

Mine transport may be of truck, railway, and conveyor belt and skip transport. In truck transport, the output from a truck in an hour

$q = 60\ c.f/T$ and $T = t1 + tf + tb + td + ts$

where $t1 = c/\alpha.\ Vsh.\ Fsh. * tsh$ $Tf = df/Vf$; $tb = db/Vb$

The face output per hour (Q) = K.q.n = K.60.c.f.n/T

Output from the mine per day = m.K.60.c.f.n/T *2*6

Considering 2 shifts production and 6 hours effective working in a shift

Generally for the face output average utilization and net utilization are considered.

Average utilization = Availability/Schedule hour

= (Schedule hour – Breakdown period)/Schedule hour

= 1 – (Breakdown/Schedule hour)

Net utilization = Utilization hour/Schedule hour = (Availability – Idle Time)/Schedule hour = 1 – (Breakdown period/Schedule hour) – (Idle Time/Schedule hour)

As the average and net utilization are much lesser than 100% so the production was hampered. Idle time is minimized by preparing Queuing models by considering haul distance, loading capacity of the dumper, capacity of the crusher, upward and downward slope minimization, etc.

3.14 FACE OUTPUT AND PRODUCTION COST RELATIONSHIP

Production cost per ton of mineral consist of two main groups of expenditure

i) Relative capital expenditure, CE = Ic/Qc, higher is the capacity of the mine, higher is the capital investment for construction.

ii) Relative revenue expenditure, RE = TRE/Qc, higher is the capacity is the mines lower is the revenue expenditure for per ton of mineral production.

A simulation model was viewed as a set of components that interact. These interactions of the components were most generally parallel in nature as opposite to a sequential one. In parallel interaction, may action were occurred simultaneously. Thus one of the essential tusks of current simulation languages was to enable the computer, which acted sequentially one step at a time.

3.15 SIMULATION MODELS

To minimize breakdown period it was badly needed to analyze them statistically by the simulation model, viz.

(i) Generation of uniformly distributed random numbers,

(ii) Generation of normally distributed random numbers

(iii) System simulation to event types analysis,

(iv) Identification of event by statistically distribution

3.16 UNIFORMLY DISTRIBUTED RANDOM NUMBERS

It was generated by multiplicative congruential generator or power residue generator (Fig……….) which consisted of

XI+1 = X1 * a (modulus M)

In the present work was done by

XI+1 = 24298 Xi + 9991 mod 199017

Ri+1 = Xi+1/m = Xi+1 / 199017

Xo = 199017 * Ro

3.17 NORMALLY DISTRIBUTED RANDOM NUMBER

These are the numbers where the probability of all the number not same. As such there was no specific table to those numbers and were generally made by converting the uniformly distributed random numbers with the help of a computer. There is lot of procedure for this conversation. Mostly computation was done like this:

Let, the independently and identically distributed random variables are X1, X2, X3……. Xd for

U (0, 1) and mean of those numbers is X.

So for U (0, 1), Expectation (E) = ½ and

Variance (V) = 1/12d and by Central Limit Theorem

$X = N (E(x), v(x)) = N (1/2, 1/\sqrt{12d})$

Or $(x-1/2) \sqrt{12d} = N (0,1)$

Thus n observed from uniform gives 1, obs. From normal. The conversion procedure which was used for solving these work are :

If R4 was a normally distributed random number (RN) with mean (μ) = 0 and standard deviation (σ) = 1 then conversation was done [Fig………] by

$RN = R4.\sigma + \mu$

where $R4 = \sqrt{[-2.In.R2]} * \cos [2\pi\ R3]$

3.18 SYSTEM SIMULATION ON EVENT TO EVENT ANALYSIS

Different sub-routine for different were prepared in this simulation model and the sub-routines were design based on the frequency distribution of different breakdown which occurred in the mine. The duration of each breakdown was analyzed and from the cumulative frequency distribution the randomizing cases were drawn because breakdown of different equipments could not follow a particular rule. So, by generating the uniform ally distributed random numbers and then converting them to a normally distributed one, it aws possibly to tell which event could come first and so on. Though case arose also a particular event occurred twice at a time. As a result, event analyses were needed for this present simulation.

3.20 EVENT IDENTIFICATION

This means to determine event which would come first, second and so on. In the present work 8 events were considered demarcating by 1, 2, 3…. 8 when breakdown of any equipment took place in the mine, and rectifying this breakdown another one went out-of-order. By statistical distribution, it was identified that which event might be from the rest event. A clock schedule of the activity was maintained and a stimulatory list was prepared from the distribution function. If more than one event was scheduled to be executed, the tie breaking rules specified by the SELECT function was determined to identify the event actually executed. For the identification of this events, a special; event sub-routines was prepared which followed the different event sub-routine and the frequency distribution help to prepare this identification.

3.21 SUB ROUTINE SKEWING OF UNIFORMALLY DISTRIBUTED RANDOM NUMBER

Mine data were analyzed and from the data histogram were prepared [Table i-iv]. It was seen that for 8 different events breakdown in the plant production was hampered. This breakdown events were not uniform ally distributed, there frequency distribution were also different. Once first event was broken down, did not mean that in the ninth term it could be broken down. This irregularities were following the normally distribution curves and there histogram were not showing smooth curves. The mean of the frequency curve was right to the mode and just reverse was also not impossible. These 8 events subroutine skewing of, was replaced to the uniform ally distributed random numbers to the histogram, the solution of the problem of much easier than the problem which were dealt in this paper.

3.22 SIMULATION OF CONTINUOUS SYSTEMS:

From the viewpoint of simulation there are two fundamentally different types of systems:

1) Systems in which the state changes smoothly or continuously with time (continuous systems).

2) Systems in which the state changes abruptly at discrete points in time (discrete systems).

Usually, the simulation of most systems in engineering and physical sciences turns out to be continuous, whereas most systems encountered in operations research and management sciences are discrete. The methodologies of discrete and continuous simulations are inherently different. Continuous dynamic systems, those systems in which the state or the variables vary continuously with time, can generally be described by means of differential equations. If the set of (simultaneous) differential equations describing a system are ordinary, linear, and time – invariant (i.e. have constant coefficients), an analytic solution is usually easy to obtain. In general differential equations of a more difficult nature can only be solved numerically. Simulating the system often gives added insight into the problem besides giving the required numerical solution.

3.23 SELECTING SIMULATION SOFTWARE

Overview of the Steps Involved in Selecting Simulation Software

The steps for selecting simulation software are outlined below (and detailed in subsequent sections):

1. Establish the commitment to invest in simulation software to solve your problem.
2. Clearly state the problem (or class of problems) that you would like to solve.
3. Determine the general type of simulation tool required to solve the problem.
4. Carry out an initial survey of potential solutions.
5. Develop a list of functional requirements.
6. Select the subset of tools that appear to best meet the functional requirements.
7. Carry out a detailed evaluation of the screened tools and select a solution.

Step 1: Establish the Commitment to Invest in Simulation Software

Before spending any effort to research simulation tools, the organization should establish the commitment to invest both the necessary money and staff time into purchasing and learning how to use a simulation software program. Depending on the type of simulation tool selected, the 15 price for a single license is likely to be no less than Usually, the simulation of most systems in engineering and physical sciences turns out to be continuous, whereas most systems encountered in operations research and management sciences are discrete. The methodologies of discrete and continuous simulations are inherently different. Continuous dynamic systems, those systems in which the state or the variables vary continuously with time, can generally be described by means of differential equations. If the set of (simultaneous) differential equations describing a system are ordinary, linear, and time –invariant (i.e. have constant coefficients), an analytic solution is usually easy to obtain. In general differential equations of a more difficult nature can only be solved numerically. Simulating the system often gives added insight into the problem besides giving the required numerical solution.

Step 2: Clearly State the Problem You Wish to Address

Perhaps the most important step in selecting simulation software is to clearly state the problem (or class of problems) that you would like to address. This must include a general statement of what you would like the simulation tool to do. Without doing so, it will be impossible to determine, first, the type of simulation tool you should look for, and subsequently, to list the functional requirements and desired attributes of the tool. To illustrate what is required, several examples of simulation problem statements are listed below:

Managing the water supply for a city:

Managing a water supply is difficult due to the dynamic (and naturally unpredictable) nature of the problem (resulting from uncertainties in both weather and demand). The simulation tool must be able to predict the movement of water through a system (e.g., reservoirs, distribution systems) tracking the quantities and flow rates at various locations. It must be able to quantitatively represent the inherent uncertainty in the system (due to the uncertainty in the weather and demand), and represent various management options (e.g., rules for allocating flows under specified 16 conditions).

The output of the simulation will consist of probabilistic predictions of daily water levels and flow rates over time given a specified management alternative. Carrying out a risk analysis for a complex mission (i.e., a machine and/or persons performing a specified task or set or tasks):

Carrying out a risk analysis for a complex mission is difficult due to the complex interactions and dependencies of the various components, and the fact that the environment may evolve dynamically during the mission. The simulation tool must be able to simulate the operation of the machine throughout the mission, explicitly modeling component interactions, dependencies and failures. It must also be able to represent the impact of a changing environment on the components. The output of the simulation will consist of probabilities of failure (and success) for a mission of specified length, and identification of key failure mechanisms.

Modelling the financial outcome of several alternative projects:

When selecting or ranking various alternative projects or undertakings, it is necessary to quantitatively evaluate both the costs and revenues associated with each project. The simulation tool must be able to simulate the future costs and revenues associated with alternative projects, explicitly accounting for the uncertainty in costs, durations and revenues. The simulation must be able to represent disruptive events (e.g. strikes, price changes) and resulting contingency plans that allow a simulated project to respond to new developments in a realistic way. The output of the simulation will consist of probabilistic predictions of the NPV and IRR for each alternative. Note that these statements are not extremely detailed, but provide a clear statement of the problem, a general statement of what processes and features must be included, and what the output of the simulation will be. This provides enough information to direct a survey of potential solutions and carry out an initial screening. In a later step in the process, more detailed requirements will need to be defined in order to differentiate between the available options.

Step 3: Determine the General Type of Simulation Tool Required

Because simulation is such a powerful tool to assist in understanding complex systems and to support decision-making, a wide variety of approaches and tools exist. Before trying to survey all available tools, you must first decide upon the general type of tool that you require. 17 There are a variety of simulation frameworks, each tailored for a specific type of problem. What they all have in common, however, is that they allow the user to model how a system might evolve or change over time. Such frameworks can be thought of as high-level programming languages that allow the user to simulate many different kinds of systems in a flexible way. Perhaps the simplest and most broadly used general purpose simulator is the spreadsheet. Although spreadsheets are inherently limited in many ways by their structure (e.g., representing complex dynamic processes is difficult, they cannot display the model structure graphically, and they require special add-ins to represent uncertainty), because of the ubiquity of spreadsheets, they are very widely used for simple simulation projects (particularly in the business world). Other general purpose tools exist that are better able to represent complex dynamics, as well as provide a graphical mechanism for viewing the model structure (e.g., an influence diagram or flow chart of some type). Although these tools are generally harder to learn to use than spreadsheets (and are typically more expensive), these advantages allow them to realistically simulate larger and more complex systems. The general purpose tools can be broadly categorized as follows:

Discrete Event Simulators: These tools rely on a transaction-flow approach to modeling systems. Models consist of entities (units of traffic), resources (elements that service entities), and control elements (elements that determine the states of the entities and resources). Discrete event simulators are generally designed for simulating processes such as call centers, factory operations, and shipping facilities in which the material or information that is being simulated can be described as moving in discrete steps or packets. They are not meant to model the movement of continuous material (e.g., water) or represent continuous systems that are represented by differential equations.

Agent-Based Simulators: This is a special class of discrete event simulator in which the mobile entities are known as agents. Whereas in a traditional discrete event model the entities only have attributes (properties that may control how they interact with various resources or control elements), agents have both attributes and methods (e.g., rules for interacting with other agents). An agent-based model could, for example, simulate the behavior of a population of animals that are moving around and interacting with each 18 character.

Continuous Simulators: This class of tools solves differential equations that describe the evolution of a system using continuous equations. Although these tools usually have some mechanism to represent discrete events, they are most appropriate if the material or information that is being simulated can be described as evolving or moving smoothly and continuously, rather than in infrequent discrete steps or packets. For example, simulation of the movement of water through a series of reservoirs and pipes can most appropriately be represented using a continuous simulator. Continuous simulators can also be used to simulate systems consisting of discrete entities if the number of entities is so large that the movement can be treated as a flow.

Hybrid Simulators: These tools combine the features of continuous simulators and discrete simulators. That is, they solve differential equations, but can superimpose discrete events on the continuously varying system. This can be useful, for example, in business simulations, in which information and material can be modeled as moving continuously, but discrete financial transactions also need to be represented Before starting your search for a simulation tool, you should first determine which of these types of tools is required to solve your problem. In most cases, this can be determined from the problem statement. If you are unsure, you should seek input from someone who is familiar with simulation modeling (e.g., a consultant). One of the worst mistakes you can make is to select the wrong type of tool (e.g., to select a continuous simulator, when what you really need is a discrete event simulator).

Step 4: Carry Out an Initial Survey of Potential Solutions

Once you have selected the general type of tool you will need, you can then carry out an initial survey to try to identify the possible options. Note that this process does not involve actively evaluating any software tools. It is simply a survey to see what options are available. The only screening that should be carried out should be based on general type. For example, if you have determined that a continuous simulation tool is required, you should screen out pure discrete event simulators. 19
This initial list of candidate tools can be generated from a variety of sources, including web searches, peer recommendations, advertisements in trade magazines, and vendor lists from trade-shows.

Step 5: Develop a List of Functional Requirements

Step 5 involves developing a set of functional requirements that you would like the software tool to have. This list will then be used in a subsequent step to compare and contrast the candidate solutions and filter out all but the most promising candidates. A functional requirement is a necessary feature or attribute of the simulation software solution. Note that requirements specify what the simulation software will do, not how. They should be as concise as possible. You should also note whether a requirement is mandatory or simply desired (e.g., "must have" in a requirement could indicate mandatory; "should have" could indicate desired, but not mandatory). In order to develop a list of requirements, you generally start with your problem statement, and describe the minimum set of functionality that will be necessary in order for the software to solve your problem. The actual users of the software will be the primary developers of the requirements list, but other stakeholders should also be involved, such as the ultimate client for the model (e.g., a manager) and IT personnel, as they may have their own requirements. To illustrate what is meant by a functional requirement, let's consider the first example problem statement listed in the description of Step 2 above: Managing the water supply for a city: Managing a water supply is difficult due to the dynamic (and naturally unpredictable) nature of the problem (resulting from uncertainties in both weather and demand). The simulation tool must be able to predict the movement of water through a system (e.g., reservoirs, distribution systems) tracking the quantities and flow rates at various locations. It must be able to quantitatively represent the inherent uncertainty in the system (due to the uncertainty in the weather and demand), and represent various management options (e.g., rules for allocating flows under specified conditions). The output of the simulation will consist of probabilistic predictions of daily water levels and flow rates over time given a specified management alternative. …..20

The list of functional requirements for this problem statement would likely include the following mandatory requirements:

- Must be able to track and conserve the continuous movement of material through a system (in this case water).
- Must be able to represent random discrete changes to the system (e.g., pump failures)
- Must be able to represent stochastic processes (e.g., rainfall).
- Must be able to represent rules for allocating and splitting flows.
- Must be able to enter time series inputs.
- Must be able to import time series inputs and other data from spreadsheets.
- Must support Monte Carlo simulation.
- Must have a user interface that supports creation of transparent, well-documented models.

Desired (but perhaps not mandatory) requirements might include:

- Should be able to easily handle unit conversions
- Should be able to support distributed processing (for Monte Carlo simulation).

- Should support optimization.
- Should provide tools for sensitivity analysis.

Step 6: Select the Subset of Tools that Appear to Best Meet the Functional Requirements

Once you have defined your functional requirements, the next step is to apply the requirements, to the candidate solutions, identifying and eliminating candidates that do not meet the mandatory requirements.

Note that this step should not require downloading and running the candidate software. Instead, the reviewer should be able to gather sufficient information to develop informed yes/no answers to the requirements based on the vendors web pages, quick tours, animated demos, white papers, case studies, recorded webinars, and in some cases, phone calls with technical sales representatives. If you cannot easily gather information about a software product, it is recommended that you eliminate that product from consideration (as this is generally an indication that the quality of the product and/or the level of support is likely to be poor).

The output of this step is a list of viable solutions, each one of which will then be evaluated in greater detail in the next step.

Step 7: Carry out a Detailed Evaluation of the Screened Tools

The final step in the process involves carrying out a detailed evaluation of the tools screened in Step 6 and selecting the most appropriate tool. To do so, you should obtain an evaluation version of each product and experiment with the software yourself. Although this is necessary, it can be time-consuming, since each product will have a learning curve.

3.24 DISCRETE SYSTEM SIMULATIONS: In this type of system the changes are discontinuous. Each change in the state of system is called an event. For example, arrival or departure of a customer in a queue is an event. Likewise, sale of an item from the stock or arrival of an order to replenish the stock is an inventory system. Arrival of a car at an intersection is an event if we are simulating street traffic. Therefore, the simulation of a discrete system is often referred to as discrete event simulation. It is commonly used by operations research workers to study large, complex systems which do not lend themselves to a conventional analytic approach. Some other examples are the study of sea and air ports, steel melting shops, telephone exchanges, production line, stock of goods scheduling of projects, to name a few. Discrete system simulation is more diverse and has less of a theory than continuous system simulation. There are no overall sets of equation to be solved in discrete – event simulation.

FIXED TIME STEP VS EVENT-TO-EVENT MODEL:

In simulating any dynamic system – continuous or discrete – there must be a mechanism for the flow of time. For we must advance time, keep track of the total elapsed time, determine the state of the system at the new point in time, and terminate the simulation when the total elapsed time equals or exceeds the simulation period. In simulation of discrete systems, there are two 22 fundamentally different models for moving a system through time: the fixed time step model and the event-to-event (or next event) model. In a fixed time-step model a "timer" or "clock" is simulated by the computer. This clock is up-dated by a fixed time interval, and the system is examined to see if any event has taken place during this time interval (minutes, hours, and days, whatever.). All events that take place during this period are treated as if they occurred simultaneously al the tail end of this interval. In a next event simulation model the computer advances time to the occurrence of the next event. It shifts from event to event. The system state does not change in between. Only those points in time are kept track of when something of interest happens to the system.

Chapter 4

CASE STUDY APPLICATION

4.1 INTRODUCTION

The technology proposed for generating optimum production schedules for using machineries reducing their breakdown hours by preventive maintenance and simulating the shovel-dumper idle hour to improve production and productivity was investigated in a lime stone fully mechanized mines. Fig 4.1 illustrates the application of the proposed methodology in the case study mine. The figures show clearly that process involved in calculation the idle hour and the reduction of idle hours and also the breakdown maintenance improve the productivity of the mines. Detailed analysis and output are presented in this chapter.

4.2 DESCRIPTION OF THE CASE STUDY MINE

The investigation was carried out The OCL Langibarna Limestone mines is fully mechanized and located at Sundergarh district, Orissa, 10 km away from Rajgangpur town. The captive cement plant is at the same place. Here the massive limestone deposit is of anticline of "Gangpur Series". The mine is divided into six nos of different pits, marked as Pit No. -1, Pit No. -2,………..Pit No. -6. The bench height of the mines is around 10 m and ore is to waste ratio is 1:1. The targeted production is 10000 MT per day but due to some constraints present production is 6000-7000 MT per day. The machineries used in the mines are Drill machine: model ROCL-6 Make Atlas Cop co; Dozer: Model D 155, 320 HP, Make Komatsu; Road grader; BEML Haul pack Dumper: of 35 MT & 50 MT; Hydraulic shovels: of 4.5 cu m. & 6.5 cu m. of bucket capacity, Make TATA Hitachi, Model PC 1250; Road Roller:10 MT; Explosive Van: 8 MT capacity; Fuel Tanker: 10 KL; water sprinkler 10KL, 18KL and 22KL; Primary crushers: 400 TPH and 1600 TPH, of L&T make; Stalker cum reclaimer: 1200 TPH of China make; Belt conveyor: Transporting from crusher to cement plant around 10 km long; Also Narrow Gauge Loco: Transport from crusher to cement plant etc.

4.3 USE OF MONTE CARLO SIMULATION TECHNIQUE IN PRO DUCTION OPTIMISATION

Simulation is a numerical technique for conducting experiments that involves certain types of mathematical and logical relationship necessary to describe the behavior and structure of a complex real world system over extended period of time. From definition it is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior (within the limit imposed by a criterion or a set of criteria) for the operation of the system. Using the simulation we can introduce the constants and variables related to the problem, set up the possible courses action and establish criteria which act as measures of effectiveness.

In this study, I illustrate the use of Monte-Carlo simulation technique in shovel dumper transport combination in the mines for primary crusher feeding for a steady-state optimized production. All the experimental data are collected from the mines.

4.3.1 CALCULATION OF OPERATING COST OF SHOVEL:

Depreciation cost = 12% (of investment cost = 1.75 crore) Avg. per year = 2.5 * 0.12 = Rs. 30.00 lakh per year i.e. 3000000/300 = Rs. 10000 per day = Rs. 1000/- per hour.

Fuel cost (HSD Oil) 75 liters per hour @ Rs. 40/- per lit. = Rs 3000/- per hour.

Maintenance & spare parts cost =20% of depreciation cost =Rs. 200/-per hour.

Operators & helpers wages = Rs. 100/- (Approx.) per hour.

So, total operating cost for shovel = a) + b) + c) + d) = Rs.(1000 + 3000 + 200 + 100) = Rs. 4300/- per hour.

4.3.2 SPECIFICATION FOR OPERATING COST OF SHOVEL AND DUMPER

Table 4.1: Specification of Shovel and Dumper

Model/make of machine	TATA HITACHI Hydraulic Shovel	BEML Dumper
Model	PC - 1250	Haulpak
Bucket capacity	6.5 cu m	50 MT
Cost of the machine	2.5 crore	1.25 crore
Life of the machine	8 years	8 years
a) Depreciation cost	Avg. 12% each year	Avg. 12% each year
b) Fuel cost	75 lits per hour	30 lits per hour
c) Maintenance & spare parts	20% of depreciation cost	20% of depreciation cost
d) Operators & helpers wages	Rs. 100/- per hour (say)	Rs. 50/- per hour (say)
Effective working hours in 2 shifts per day	10 hours per day	10 hours per day
Working days in a year	300 days	300 days

4.3.3 CALCULATION OF OPERATING COST OF DUMPER:

Depreciation cost = 12% (of investment cost = 1.25 crore) Avg. per year = 1.25 * 0.12 = Rs. 15.00 lakh per year i.e. 1500000/300 = Rs. 5000 per day = Rs. 500/- per hour.

Fuel cost 30 liters per hour @ Rs. 40/- per lit. = Rs 1200/- per hour.

Maintenance & spare parts cost = 20% of depreciation cost =Rs. 100/-per hr.

Operators & helpers wages = Rs. 50/- (Approx.) per hour.

So, total operating cost for shovel = a) + b) + c) + d) = Rs.(500 + 1200 + 100 + 50) = Rs. 1850/- per hour.

Now at Pit No. -6 haul pack dumpers of 50 MT capacities are loaded with ROM for crusher feeding with a shovel of 6.5 cu m bucket capacity, which has the following characteristics:

The mean arrival rate of dumpers and mean loading time are (lead distance 2 km avg. @ speed 20-25 km per hour of the dumpers) 6.2 minutes 5.5 minutes respectively. The time between arrival and its (cycle time) loading varies from 1 minute to 7 minutes. The arrival and loading time distribution are given below:

Table 4.2: Arrival and Loading Distribution

Time(minutes)	Arrival(probability)	Loading(probability)
1 – 2	0.05	0.10
2 – 3	0.20	0.20
3 – 4	0.35	0.40
4 – 5	0.25	0.20
5 – 6	0.10	0.10
6 - 7	0.05	--

The queuing process starts at 7:00 A.M. and the calculation done up to 8:00 A.M. i.e. for 1 (one) hour interval only. An arrival of dumper immediately moves to spot for availing the loading facility if the shovel is idle.

On the other hand, if the shovel is busy the dumper will wait on the queue. Dumpers are loaded on the first come first serve basis.

Using Monte-Carlo simulation technique from the given frequency distribution of arrival and loading times, the probabilities and cumulative probabilities are first worked out as shown below. These, then become the basis for generating arrival and loading times in conjunction with a table of random numbers:

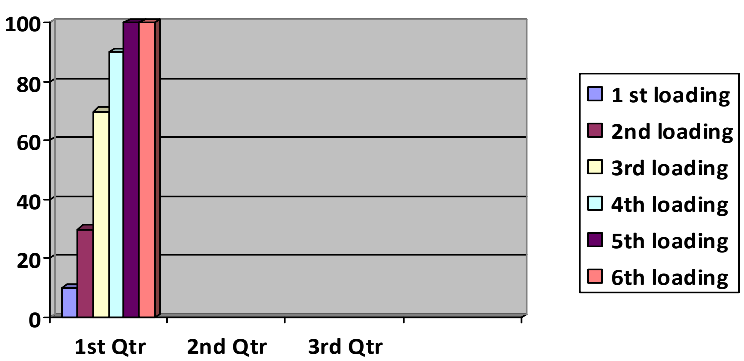

Fig 4.1: Cumulative probabilities vs time between interval (minutes)

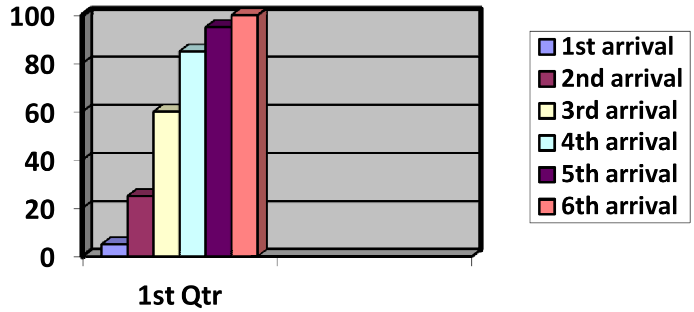

Fig 4.2: Cumulative probabilities vs loading time (minutes)

Table 3: Cumulative probability
Table 4: Cumulative probability

Time between arrival (minutes)	Cumulative probability
1-2	0.05
2-3	0.25
3-4	0.60
4-5	0.85
5-6	0.95
6-7	1.00

Loading Time (minutes)	Cumulative probability
1-2	0.10
2-3	0.30
3-4	0.70
4-5	0.90
5-6	1.00
6-7	1.00

As we have to use random number table, first of all we allot the random numbers to various intervals as shown in the table below.

Table 4.5: Random number coding for inter arrival time.

Inter arrival time(minute)	Probability	RN allotted
1-2	0.05	00-04
2-3	0.20	05-24
3-4	0.35	25-59
4-5	0.25	60-84
5-6	0.10	85-94
6-7	0.05	95-99

Table 4.6: Random number coding for loading time.

Loading time(minutes)	Probability	RN allotted
1-2	0.10	00-09
2-3	0.20	10-26
3-4	0.40	30-69
4-5	0.20	70-89
5-6	0.10	90-99
6-7	0.00	--

Table 4.7: The following information can be obtained from the above simulation work-sheet based on the period of one hour only.

RN	Inter arrival time	Arrival time(AM)	Loading begins (AM)	RN	Loading		Waiting time (min)		
					Time (min)	Ends (AM)	Shovel	Dumper	Line length
31	3	7:03	7:03	35	3	7:06	3	-	-
65	4	7:07	7:07	78	4	7:11	1	-	-
03	1	7:08	7:11	09	1	7:12	-	3	-
79	5	7:13	7:13	47	3	7:16	1	-	-
24	3	7:16	7:16	51	4	7:20	-	-	-
36	3	7:19	7:20	89	5	7:24	-	1	1
88	5	7:24	7:24	13	2	7:26	-	-	-
45	4	7:28	7:28	36	3	7:31	2	-	-
04	2	7:30	7:31	74	4	7:35	-	1	1
16	3	7:33	7:35	61	4	7:39	-	2	1
65	4	7:37	7:39	63	4	7:43	-	2	1
55	4	7:41	7:43	11	2	7:45	-	4	1
96	6	7:47	7:47	02	1	7:48	2	-	-
02	1	7:48	7:48	42	3	7:51	-	-	-
71	4	7:52	7:52	59	4	7:56	1	-	-
52	4	7:56	7:56	05	1	7:57	-	-	-
13	2	7:58	7:58	08	2	8:00	1	-	-
	58				50		11	13	5

The random number develop are related to the cumulative probability distribution of arrival and loading time. The first random number of arrival time is 31. This number lies between 25 and 59 and indicates a simulated arrival time of 3 minutes. All simulated arrival and loading times have been worked out in a similar fashion.

After generating the arrival and loading times from a table of random numbers, the next step is to list the arrival time in the appropriate Colum. The first arrival comes in 3 minutes after the starting time. This means the shovel waited for 3minutes initially. It has been shown under the Colum-waiting time: shovel. The first random number of loading time is 79. This number lies between 70 and 89. So, the simulated loading time for the first arrival is 4 minutes which result in the loading begins at 7:03 AM and completed in 7:07 AM. The next arrival comes at 7:08.

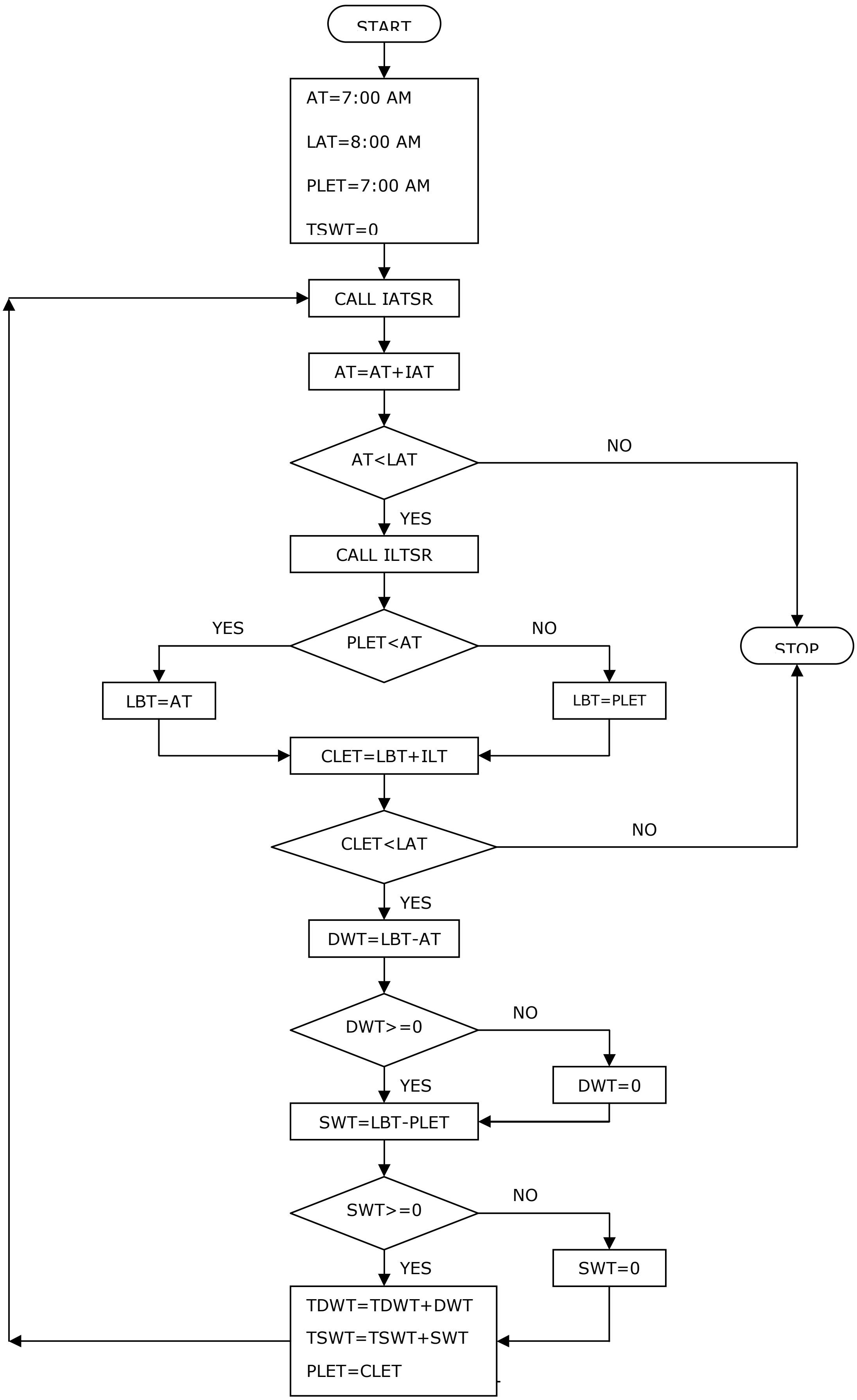

Fig. 4.8: Flow Chart Showing Simulation Work-Sheet

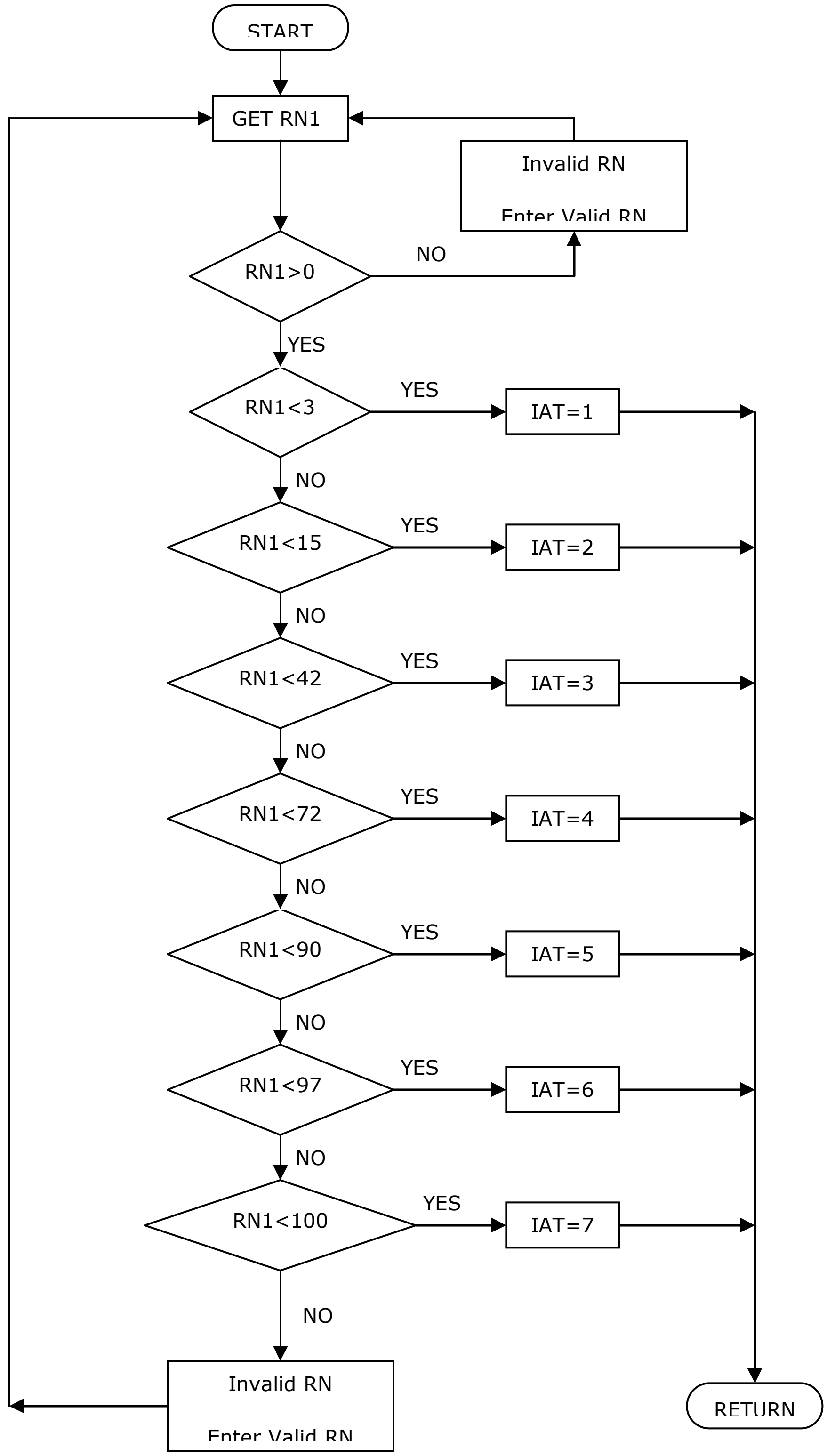

Fig. 4.9: Flow Chart Showing Sub-Routine Inter Arrival Time

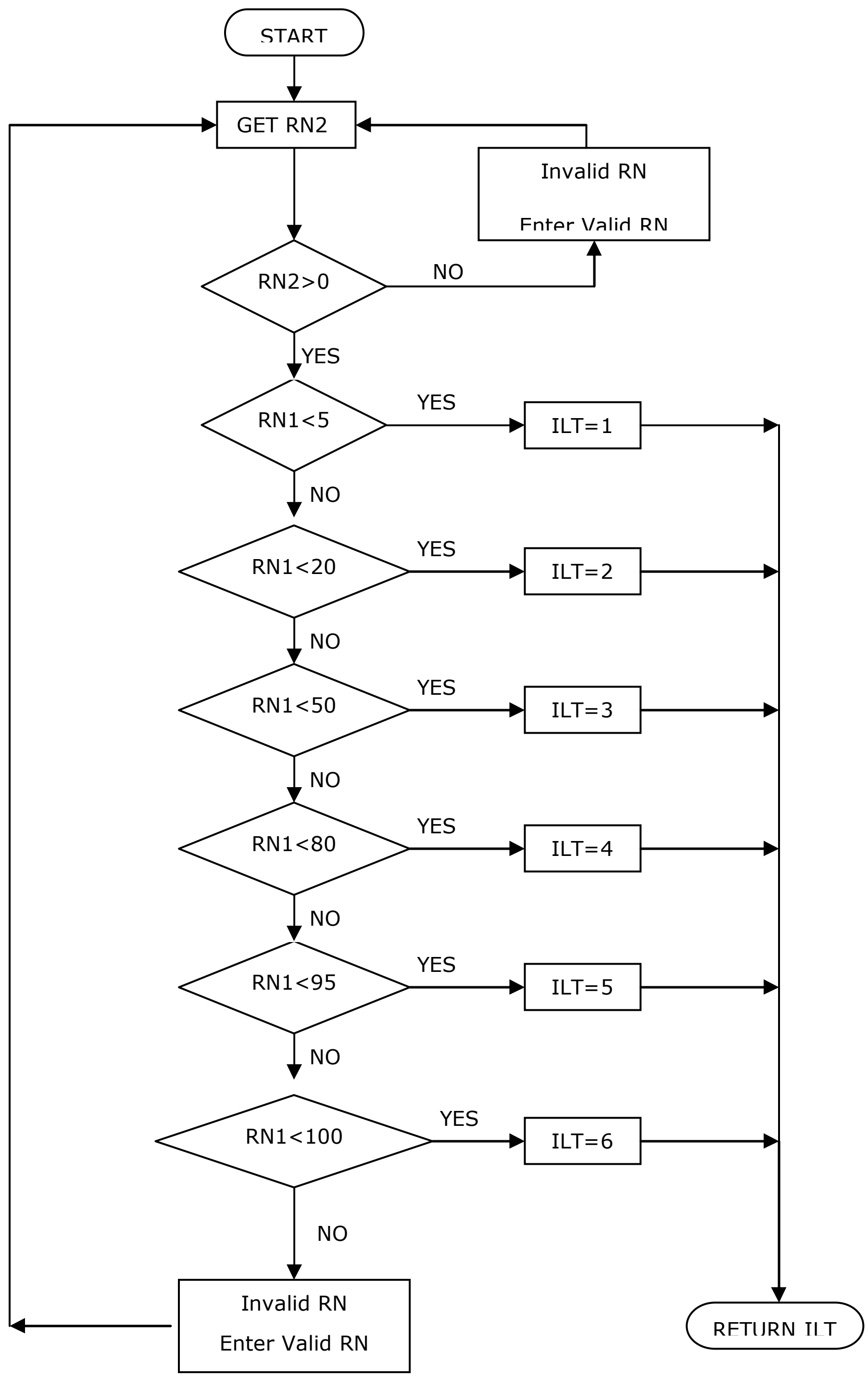

Fig. 4.10: Flow Chart Showing Sub-Routine Inter Loading Time

4.4 RESULTS:

The following information can be obtained from the above simulation work sheet based on the period one hour only.

a) Average Queue Length = No of dumpers in the waiting line /No. = 5/17

= 0.294

b) Average Waiting Time for the Dumper before Loading = Dumper waiting time / No of Arrivals = 13/17 = 0.76

c) Average Loading Time = Total Loading Time/No of Arrival = 50 / 17 = 2.94 minutes

d) Time a Dumper Spend in the System = Average Loading Time + Average Waiting Time before Loading = 2.94 + 0.76 = 3.70 minutes

4.4 CONCLUSION:

Simulation Work-Sheet developed in this problem also states that if one or more dumper is added in the system. There is no need for a dumper to wait in the queue. But, before effecting any decision, the cost of having an additional shovel has to compare with the cost due to dumper waiting time. This can be worked out as follows:

Table 4.11: Cost Comparison of with one Shovel and with two Shovels

One hour period	Cost with one shovel	Cost with two shovels
Dumper waiting time 13 minutes * Rs 1850/- per minutes	Rs 401/-	Nil
Shovel cost	Rs 4300/-	Rs 8600/-
Total cost for one hour period	Rs 4701/-	Rs 8600/-

So, we see clearly that for one hour period dumper loss 13 minutes for which provide of one additional shovel will not be a wise decision. The same way we can calculate the cost of one additional dumper which is to be compared with time loss due shovel waiting time.

Table 4.12: Cost Comparison of with existing dumper and one additional dumper.

One hour period	Cost with existing dumper	Cost with one additional dumper
Shovel waiting time(11 minutes *Rs 4300/-)	Rs 788/-	Nil
Dumper's cost	N	N + 1850/-
Total cost of one hour period	N + 788/-	N + 1850/-

Also addition of one more dumper is costlier than the no of existing dumper with shovel loss due to waiting time. Hence the selection of equipment is optimum with this simulation work sheet. Now, it depends on management's philosophy that if they want to calculate maximum loss due to shovel and dumper is manageable but at the same time the primary crusher will be idle, and the entire transporting system will be idle, etc these will cost drastic production loss. So, one more shovel or dumper or both are to be added in the system whichever is less though it is not economic, but in greater sense it will help to continue the entire system and much economical.

4.6 PERFORMANCE APPRAISAL OF MINING MACHINARIES

The 10 events which were identified from the mine data analyzed were:

Even 1 : Breakdown of shovel

Event 2 : Breakdown of Dumper,

Event 3 : Breakdown of drilling machineries,

Event 4 : Breakdown of Dozer,

Event 5 : Breakdown of Primary crusher

Event 6 : Tripping of Conveyor belt

Event 7 : General maintenance,

Event 8 : Power Failure

Event 9 : Breakdown of Narrow gauged rail transport

Event 10 : Breakdown of reclaimer

The breakdown data of all the 10 events were analyzed for a period of two years. A specific example is shown below:

4.7 Specific example for data analysis

The list of following tables shows the break-down data analysis of different machineries.

Table 4.10: Frequency and period of existence of breakdown of shovel

Date	Time needed in hours	Frequency of Shovel Breakdown	Period of existence in hours
12.04.2009	--	--	
15.04.2009	96	1	6.331
16.04.2009	24	1	15.101
29.04.2009	312	1	5.511
01.11.2009	48	1	3.887
02.11.2009	24	1	3.218
16.11.2009	336	1	0.367
17.11.2009	24	1	4.110
18.11.2009	24	1	15.650
29.11.2009	264	1	3.698
30.11.2009	24	1	2.650
17.12.2009	408	1	0.235

Table 4.11: Conversion of interval between shovel break-downs to cumulative random numbers

Interval between shovel breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	7	7000	0 - 7000
200-300	1	1000	7001-8000
300-400	2	2000	8001-10,000
400-500	1	1000	10,001-11,000
	11	11,000	

Table 4.12: Conversion of Existence of Shovel Breakdown to cumulative random numbers

Existence of shovel breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	2	2000	0-2000
2-3	1	1000	2001-3000
3-4	3	3000	3001-6000
4-5	1	1000	6001-7000
5-6	1	1000	7001-8000
6-7	1	1000	8001-9000
15-16	2	2000	9001-11,000
	11	11,000	

Table 4.13: Frequency and period of existence of breakdown of dumper

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	72	1	0.645
16.04.2009	24	1	0.231
29.04.2009	72	1	2.331
01.11.2009	48	1	0.687
16.11.2009	360	1	6.450
17.11.2009	24	1	15.220
18.11.2009	24	1	3.335
29.11.2009	264	1	16.000
30.11.2009	24	1	5.660
17.12.2009	408	1	2.275
22.12.2010	504	1	5.020

Table 4.14: Conversion of interval between Dumper break-downs to cumulative random numbers

Interval between dumper breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	7	7000	0 – 7000
200-300	1	1000	7001-8000
300-400	1	1000	8001-9000
400-500	1	1000	9001-10,000
500-600	1	1000	10,001-11,000
	11	11,000	

Table 4.15: Conversion of Existence of Dumper breakdown to cumulative random numbers

Existence of dumper breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	3	2000	0-2000
2-3	2	1000	2001-3000
3-4	1	3000	3001-6000
5-6	1	1000	6001-7000
6-7	1	1000	7001-8000
15-16	2	1000	9001-10,000
	10	10,000	

Table 4.16: Conversion of interval between Drill Machine break-downs to cumulative random numbers

Interval between drill machine breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	7	7000	0 - 7000
200-300	2	2000	7001-9000
300-400	1	1000	9001-10,000
800-900	2	2000	10,001-12,000
	12	12,000	

Table 4.17: Frequency and period of existence of breakdown of Drill Machine

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	72	1	6.500
16.04.2009	24	1	3.650
29.04.2009	208	1	3.554
01.11.2009	48	1	8.554
02.11.2009	24	1	2.750
16.11.2009	336	1	15.500
17.11.2009	24	1	14.550
18.11.2009	24	1	5.000
29.11.2009	264	1	1.500
30.11.2009	24	1	0.550
05.01.2010	840	2	1.250

Table 4.18: Conversion of Existence of Drill Machine breakdown to cumulative random numbers

Existence of drill machine breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	1	1000	0-1000
1-2	3	3000	1001-4000
2-3	1	1000	4001-5000
3-4	2	2000	5001-7000
5-6	1	1000	7001-8000
6-7	1	1000	8001-9000
8-9	1	1000	9001-10,000
14-15	1	1000	10001-11000
15-16	1	1000	11001-12,000
	12	12,000	

Table 4.19: Frequency and period of existence of breakdown of Dozer

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	360	1	2.330
16.04.2009	24	1	5.011
29.04.2009	312	1	0.329
01.11.2009	48	1	1.117
02.11.2009	24	1	0.358
16.11.2009	336	1	15.116
17.11.2009	24	1	6.238
18.11.2009	24	1	4.981
29.11.2009	264	1	2.258
30.11.2009	24	1	1.661
17.12.2009	408	1	9.884
18.12.2009	12	1	3.337

Table 4.20: Conversion of interval between Dozer break-downs to cumulative random numbers

Interval between dozer breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	7	7000	0 - 7000
200-300	1	1000	7001-8000
300-400	3	3000	8001-11,000
400-500	1	1000	11,001-12,000
	12	12,000	

Table 4.21: Conversion of Existence of Dozer breakdown to cumulative random numbers

Existence of dozer breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	2	2000	0-2000
1-2	2	2000	2001-4000
2-3	2	2000	4001-6000
3-4	1	1000	6001-7000
4-5	1	1000	7001-8000
5-6	1	1000	8001-9000
6-7	1	1000	9001-10,000
9-10	1	1000	10,001-11,000
15-16	1	1000	11,001-12000

Table 4.22: Frequency and existence of breakdown of Primary Crusher

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	336	1	2.300
16.04.2009	24	1	6.500
29.04.2009	312	1	4.201
01.11.2009	48	1	0.335
02.11.2009	24	1	11..225
16.11.2009	224	1	5.555
18.11.2009	48	1	2.228
29.11.2009	264	1	2.550
30.11.2009	24	1	0.650
17.12.2009	408	1	1.250
18.12.2009	24	1	3.650
05.03.2010	1488	1	7.500

Table 4.23: Conversion of interval between Primary Crusher break-downs to cumulative random number

Interval between primary crusher breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	6	6000	0 - 6000
200-300	2	2000	6001-8000
300-400	2	2000	8001-10,000
400-500	1	1000	10,001-11,000
1400-1500	1	1000	11,001-12,000
	12	12,000	

Table 4.24: Conversion of Existence of Primary Crusher breakdown to cumulative random numbers

Existence of primary crusher breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	2	2000	0-2000
1-2	1	1000	2001-3000
2-3	3	3000	3001-6000
3-4	1	1000	6001-7000
4-5	1	1000	7001-8000
5-6	1	1000	8001-9000
6-7	1	1000	9001-10,000
7-8	1	1000	10,001-11,000
11-12	1	1000	11,001-12,000
	12		12,000

Table 4.25: Frequency and period of existence of Tripping of Belt Conveyor

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	816	1	6.500
16.04.2009	24	1	6.225
29.04.2009	312	1	4.000
01.11.2009	4368	1	0.250
02.11.2009	24	1	1.050
16.11.2009	336	1	7.018
21.11.2009	120	1	1.257
30.11.2009	216	1	3.897
17.12.2009	408	1	4.008
18.12.2009	24	1	12.050
06.03.2010	1632	2	7.225
28.05.2010	1992	2	6.665
29.06.2010	744	1	0.254

Table 4.26: Conversion of interval between Belt Conveyor break-downs to cumulative random numbers

Interval between belt conveyor breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	3	3000	0 - 3000
100-200	1	1000	7001-8000
200-300	1	1000	8001-9000
300-400	2	2000	9001-11,000
400-500	1	1000	11,001-12,000
700-800	1	1000	12,001-13,000
800-900	1	1000	13,001-14,000
1600-1700	2	2000	14,001-16,000
1900-2000	2	2000	16,001-18,000
4300-4400	1	1000	16,001-17,000
	15	15,000	

Table 4.27: Frequency and period of existence of breakdown of Rail Transport

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	792	1	3.210
20.04.2009	120	1	2.500
29.06.2009	1680	1	6.500
01.11.2009	2880	2	12.000
06.11.2009	120	1	5.122
17.11.2009	264	1	0.365
18.11.2009	24	2	2.225
29.11.2009	264	2	4.550
17.12.2009	432	1	7.564
19.12.2009	60	1	4.124
26.03.2010	2400	2	2.550
17.04.2010	528	1	8.120
23.05.2010	864	1	0.336

Table 4.28: Conversion of Existence of Belt Conveyor breakdown to cumulative random numbers

Existence of belt conveyor breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	2	2000	0-2000
1-2	2	2000	2001-4000
3-4	1	1000	4001-5000
4-5	2	2000	5001-7000
6-7	4	4000	7001-11,000
7-8	3	3000	11,001-14000
12-13	1	1000	14,001-15,000
	15	15,000	

Table 4.29: Conversion of interval between Rail Transport break-downs to cumulative random numbers

Interval between rail transport breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	3	3000	0 - 3000
100-200	2	2000	3001-5000
200-300	3	3000	5001-8000
400-500	1	1000	8001-9,000
500-600	1	1000	9,001-10,000
700-800	1	1000	10,001-11,000
800-900	1	1000	11,001-12,000
1600-1700	1	1000	12,001-13,000
2400-2500	2	2000	13,001-15,000
2800-2900	2	2000	15,000-17,000
	17	17,000	

Table 4.30: Conversion of Existence of Rail Transport breakdown to cumulative random numbers.

Existence of rail breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	2	2000	0-2000
2-3	5	5000	2001-7000
3-4	1	1000	7001-8000
4-5	3	3000	8001-11,000
5-6	1	1000	11,001-12,000
6-7	1	1000	12,001-13,000
7-8	1	1000	13,001-14,000
8-9	1	1000	14,001-15,000
12-13	2	2000	15,001-17,000
	17	17,000	

Table 4.31: Frequency and period of existence of breakdown of electric sub-station, transformer and other electric equipments

Date	Time needed in hours	Frequency	Period of existence in hours
15.04.2009	336	2	5.010
16.04.2009	36	1	0.400
29.04.2009	312	1	1.195
02.07.2009	1488	1	1.500
02.11.2009	2880	1	2.575
16.11.2009	336	1	0.575
17.11.2009	36	1	3.362
18.11.2009	24	2	11.200
29.11.2009	264	1	2.500
30.11.2009	36	1	8.597
17.12.2009	408	1	2.528
18.12.2009	24	1	4.414
05.01.2010	432	1	5.000
06.1.2010	24	2	6.321
08.02.2010	48	2	1.255
10.02.2010	60	1	2.125
19.02.2010	216	1	5.589
25.03.2010	816	1	9.994
30.03.2010	120	1	3.556
30.04.2010	744	1	0.255
29.05.2010	696	2	11.255

Table 4.32: Conversion of interval between Belt Conveyor break-downs to cumulative random numbers

Interval between belt conveyor breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	11	11000	0 - 11000
100-200	1	1000	11,001-12,000
200-300	2	2000	12,001-14,000
300-400	4	4000	14,001-18,000
400-500	2	2000	18,001-20,000
600-700	2	2000	20,001-22,000
700-800	1	1000	22,001-23,000
800-900	1	1000	23,001-24,000
1400-1500	1	1000	24,001-25,000
2800-2900	1	1000	25,001-26,000
	26	26,000	

Table 4.33: Conversion of Existence of electric sub-station etc. Break down to cumulative random numbers

Existence of shovel breakdown	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	3	3000	0-3000
1-2	4	4000	3001-7000
2-3	4	4000	7001-11,000
3-4	2	2000	10,001-13,000
4-5	1	1000	13,001-14,000
5-6	4	4000	14,001-18,000
6-7	2	2000	18,001-20,000
8-9	1	1000	20,001-21,000
9-10	1	1000	21,001-22,000
11-12	4	4000	22,001-26,000
	26	26,000	

Table 4.34: Frequency and period of existence for General Maintenance

Date	Time needed in hours	Frequency	Period of existence in hours
16.04.2009	816	1	1.230
29.04.2009	72	1	0.891
01.08.2009	2116	1	5.559
02.11.2009	2208	2	0.423
16.11.2009	336	2	3.544
17.11.2009	24	1	3.801
18.11.2009	36	1	0.654
17.12.2009	720	1	4.220
18.12.2009	36	1	7.110
05.01.2010	432	1	5.558
06.01.2010	24	1	2.000
14.02.2010	912	2	1.141
26.02.2010	288	1	0.631
03.03.2010	168	1	7.554
04.03.2010	36	1	2.910
13.03.2010	216	1	11.250
25.03.2010	300	1	9.119
26.03.2010	24	2	8.429
		22	

Table 4.35: Conversion of interval between General Maintenances to cumulative random numbers

Interval between general maintenances	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	8	8000	0 - 8000
100-200	1	1000	8001-9000
200-300	2	2000	9001-11,000
300-400	3	3000	11,001-14,000
400-500	1	1000	14,001-15,000
700-800	1	1000	15,001-16,000
800-900	1	1000	16,001-17,000
900-1000	2	2000	17,001-19,000
2100-2200	1	1000	19,001-20,000
2200-2300	2	2000	20,001-22,000
	22	22,000	

Table 4.36: Conversion of Existence for General Maintenance to cumulative random numbers

Existence of general maintenance	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	4	4000	0-4000
1-2	3	3000	4001-7000
2-3	2	2000	7001-9,000
3-4	3	3000	9,000-12,000
4-5	2	2000	12,001-14,000
5-6	2	2000	14,001-16,000
7-8	2	2000	16,000-18,000
8-9	2	2000	18,001-20,000
9-10	1	1000	20,000-21,000
11-12	1	1000	21,001-22,000
	22	22,000	

Table 4.37: Frequency and period of existence of Reclaimer Break-down

Date	Time needed in hours	Frequency	Period of existence in hours
06.04.2009	600	1	1.230
29.04.2009	552	1	0.891
01.08.2009	2116	1	5.559
02.09.2009	744	2	0.423
06.11.2009	1536	2	3.544
17.11.2009	264	1	3.801
18.11.2009	36	1	0.654
17.12.2009	720	1	4.220
18.12.2009	24	1	7.110
05.01.2010	432	1	5.558
06.01.2010	36	1	2.000
14.02.2010	912	2	1.141
28.02.2010	336	1	0.631
03.03.2010	144	1	7.554
04.03.2010	36	1	2.910
13.03.2010	216	1	11.250
26.03.2010	312	1	9.119
26.04.2010	742	2	8.429

Table 4.38: Conversion of interval between reclaimer breakdown to cumulative random numbers

Interval between reclaimer break down	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random numbers
0-100	4	4000	0 - 4000
100-200	1	1000	4001-5000
200-300	2	2000	5001-7,000
300-400	2	2000	7001-9000
400-500	1	1000	9001-10,000
500-600	1	1000	10,000-11,000
600-700	1	1000	11,001-12,000
700-800	5	5000	12,001-17,000
900-1000	2	2000	17,001-19,000
1500-1600	2	2000	19,001-21,000
2100-2200	1	1000	21,001-22,000
	22	22,000	

Table 4.39: Conversion of Existence for breakdown of Reclaimer to cumulative random numbers

Existence of reclaimer break down	Frequency of occurrence	Frequency of occurrence % * random nos	Cumulative random nos
0-1	5	5000	0-5000
1-2	3	3000	5001-8000
2-3	2	2000	8001-10,000
3-4	3	3000	10,001-13,000
4-5	1	1000	13,001-14,000
5-6	2	2000	14,001-16,000
7-8	2	2000	16,001-18,000
8-9	2	2000	18,001-20,000
9-10	1	1000	20,001-21,000
11-12	1	1000	21,001-22,000
	22	22,000	

Table 4.40: Different Events of Break-downs, their frequencies, and random-number distribution.

Sl No	Different Events of Breakdown	Total frequency of Breakdown	Frequency of breakdown in %	Random Number Distriution
1	Breakdown of Shovel	11	6.875	6875
2	Breakdown of Dumper	10	6.250	6250
3	Breakdown of Drill Machine	12	7.500	7500
4	Breakdown of Dozer	12	7.500	7500
5	Breakdown of Primary Crusher	12	7.500	7500
6	Tripping of Belt Conveyor	15	9.375	9375
7	Breakdown of Narrow Gauge Rail Transport	17	10.625	10625
8	Power Failure	26	16.250	16250
9	General Maintenance	23	14.375	14375
10	Breakdown of Reclaimer	22	13.750	13750
		160	100	1,00,000

From the above mentioned analysis it is observed that the random number distribution can give some indication about the occurrences of the break-down of different events like;

Table 4.41: Indicating Occurrences of break-down using random number distribution

Sl No	Events	Distribution of random number
1	Breakdown of Shovel	1 – 6875
2	Breakdown of Dumper	6876 - 13125
3	Breakdown of Drill Machine	13126 - 20625
4	Breakdown of Dozer	20626 - 28125
5	Breakdown of Primary Crusher	28126 - 35625
6	Tripping of Belt Conveyor	35626 – 45000
7	Breakdown of Narrow Gauge Rail Transport	45001 – 55625
8	Power Failure	55626 – 71878
9	General Maintenance	71879 – 86250
10	Breakdown of Reclaimer	86251 – 100,000

PROGRAMMING FOR RANDOM NUMBER OF DIFFERENT EVENTS

```
# include<iostrem.h>
# include<conio.h>
# include<stdlib.h>
# include<time.h>
Int  UNRAND ();
Int_EVENTS_IDENTIFICATION ();
Void main ()
{
clscr ();
Int R;
Randomized ();
R = random (100000);
cout<<”Uniform Random Number R =”<<R<</n”
cout <<”For this R The Event Generated is :/n”;
If (R<6876)
cout <<”Event -1: Break-down of Shovel”;
else if (R>=6876 && R<13126)
cout <<”Event -2: Break-down of Dumper”;
else if (R>=13126 && R<20126)
cout <<”Event -3: Break-down of Drill Machine”;
else if (R>=20626 && R<28126)
Cout <<”Event -4: Break-down of Dozer”;
```

```
else if (R>=28126 && R<35626)
cout <<”Event -5: Break-down of Primary Crusher”;
else if (R>=35626 && R<45001)
cout <<”Event -6: Tripping of Belt Conveyor”;
else if (R>=45001 && R<55626)
cout <<”Event -7: Break-down of Narrow Gauge Rail Transport”;
else if (R>=55226 && R<71878)
cout <<”Event -8: Power Failure”;
else if (R>=71879 && R<86250)
cout <<”Event -9: General Maintenance”;
else if (R>=86251 && R<100000)
cout <<”Event -10: Break-down of Dumper”;
getch ()
}
```

Chapter 5

SUMMARY AND CONCLUSION

Production scheduling along with production planning, provides projections of future mining progress and time requirements for the development and extraction of a resource. These schedules and plans are used by management as means of attaining the following objections;-

(1) Maintaining or maximizing expected profit,

(2) Determining future investment in mining,

(3) Optimizing return on investment, (ROI)

(4) Evaluating alternative investments, and

(5) Conserving and developing owned resourced.

The first four goals are generally concerned with mining cost, both capital and operation requirements, and as such, play an important role a production planning. However, this chapter is concerned with the fifth management objective of resource development in order to conserve and perpetuate the corporate entity. The following discussion is based on the premise that detailed economic evaluations and market surveys have been performed and analyzed and that the results indicate a viable projects.

Simulation Work-Sheet developed in this problem also states that if one or more dumper is added in the system. There is no need for a dumper to wait in the queue. But, before effecting any decision, the cost of having an additional shovel has to compare with the cost due to dumper waiting time. This can be worked out in reference to table no 4.11 and 4.12.

The breakdown of different machineries is analyzed with random number distribution. The different event falls under definite random number distribution range. Such as if random number comes as 1 - 6875 indicates the shovel breakdown and if it comes 6876- 13125 it will be considered as dumper break-down, etc. Hence a clear idea can be made for the break-down of different machineries also precautions can be taken for preventive maintenance to minimize these break-down periods by analyzing this method and thus production can be set as Optimum and steady-state.

REFERENCES

1. Deo, Narsingh, (1979) System simulation with digital computer, Prentice Hall India,
2. Wilke F. L., Mueller K. and Wright E. A. (1984), Ultimate Pit and Production Scheduling Optimization, Proceedings of 18th International Symposium on Application of computer and Operating Research in the Mineral Industry, London 26th – 30th March, London: The Institution of Mining and Metallurgy, First Edition, pp. 29-38.
3. Ramajon, S. and Dimitrakopoulos, R. (2003), Production Scheduling Optimization in a Nickle Laterite Deposite; MIP and LP Application and Infeasibility in the Presence Ore Body Variability, Proceedings of the 12th International Symposium on Mine Planning and Equipment Selection, Kalgoorlie, 23rd – 25th April, Kuruppu, M. D. and Lilly, P.A. (Eds), Carlton: Australian Institute of Mining and Metallurgy, pp. 1-5.
4. Ramajon, S. and Dimitrakopoulos, R. (2004), Traditional and New MIP Models for Production Scheduling with In-Situ Grade Variability, International Journal of Mining Reclamation and Environment, Vol. 18, No. 2, pp. 85-98.
5. Ramajon, S. and Dimitrkopoulos, R. (2007), Stochastic Optimization of Long Term Production Scheduling for Open Pit Mines With a New Integer Programming Formulation, Ore Body Modelling and Strategic Mine Planning, Dimitrakopolous, R. (Ed), Carlton: Australasian Institute of Mining and Metallurgy, Spectrum Series, Vol. 14, First Edition, pp. 353-360.
6. Praehofer, H., (1991) "System Theoretic Foundation of Combined Discrete Continued System Simulation", Doctoral dissertations Johannes Kepler University of Ling, Ling, Austria.
7. Seong, M. Cho, and T. G. Kin, (1998) "Real-Time DEVS Simulation: Concurrent, Time-Selective Execution Combined RT-DEVS Model and Interactive Environment", Proceedings of SCSC-98, July 19-22, 1998, Reno, NV, PP. 410-415.
8. Takahashi, S., and Y. Takahara, (1995) Logical Approach of System Theory. Springer-Verlag, London, 1995.
9. Wymore, A. W., (1993) Model-Based Systems Engineering: An Introduction to the Mathematical Theory of Discrete System and to the Tricotyledon Theory of System Design. CRC Press, 1993.
10. Zeigler, B. P., and J. S. Lee. (1998) Theory of Quantized Systems: Formal Basis for DEVS/HLA Distributed Simulation Environment. Enabling Technology for Simulation (II), SPIE Aeorosense 98. Orlando, FL, 1998.
11. Arik, A. (1999), An Alternative Approach Research Resourece Classification Proceedings of 28th International Symposium on Application of Computer Method in the Mineral

Industry, Golden, Colorado, 20th-22nd October, Dagdelen K., Dardano C., Fransisco M. and Proud J. (Eds.), Golden: Colorado Scool of Mines, First Edition, pp. 45-53.

12. Bagchi, T. P. (1999), Multi Objective Scheduling by Genetic Algorithm, Boston: Kluwer Academic, First Edition.

13. Caers, J. (2000), Adding Local Accuracy to direct sequential Simulation, Mathematical Geology, Vol. 32, No. 7, pp. 815-850.

14. Chakraborty, N., Sreevathsan, R., Jayakanth, R., Bhattacharya, B. (2009), Tailor-Made Material Design: An Evalutionary Approach Using Multi Objective Genetic Algorithms, Computational Materials Science, Vol. 45, No. 1, pp. 1-7.

15. Dagdelen, K. (2005), Open Pit Optimization- Strategic for Improving Economic Mine Planning, Ore Body Modelling and Strategic Mine Planning – Uncertainity and Risk Management Model, Dimitrakopoulos, R. (Eds.), Karlton Victoria: Australasian Institute of Mining Metallurgy, Spectrum series, Vol. 14, pp. 125-128.

16. Denbi, B. and Schofild, D. (1994), Open pit Design and Scheduling by use of Genetic Algorithms, Transaction of Institute of Mining and Metallurgy, Section A, Vol. 103, pp. A 221- A 226.

17. Dimitrakopoulos, R. (1998), Conditional Simulation Algorithms for Modeling Ore Body Uncertainty in Open Pit Optimization, International Journal of Mining, Reclamation and Environment, Vol. 12, No. 4 pp. 193-197.

18. Dimitrakopoulos, R. and Ramajon, S. (2004), Uncertainty Based Production Scheduling in Open Pit Mining, Society of Mining and Metallurgy, and Exploration Transaction, Vol.316, pp. 106-112.

19. Dowd, P. A. (1994), Risk Assessment in Reserve Estimation and Open Pit Planning. Transaction of Institute of Mining and Metallurgy, Section A, Vol. 103, pp. A 148 - A154.

20. Dowd, P. and Onur, A. (1992), Optimizing Open Pit Design and Sequence, Proceedings of 30th International Symposium on Application of Computer and Operation Research in the Mineral Industry, Tucson, Arizona, 7th -11th April, Kim Y. C. (Ed.), Littleton: Society for Mining, Metallurgy, and Exploration, First Edition, pp. 411-422.

21. Radhakrishnan, V. R. and Sen, P., (1982), Optimum nos of Storage Bins for Off-Specification products by Mote-Carlo Simulation, Indian Chemical Engineer, pp. 16 – 23.

22. Sentiappan, R. and Roy, S. C. (1983) Application of Queuing Theory in Open pit Equipment Selection, Tr. Mining, Geology, Metallurgy, Inst. India, pp. 80-92.

23. Pal, B. K., (1984). Simulation of the Rapid Loading System of an Iron Ore Processing Plant, M.Tech. Thesis I.I.T. Kharagpur.

24. Hausner Bemard, Harry, M. Marcowitz, Herbert, W. Karr, (1963) Simscript a Simulation Programming Language, Prentice Hall, India. pp. 56-72.

25. Hammersly, J. M. and Handcomb, D. C. (1964) Monte-Carlo Methods, Jhon Wiley and Sons, Newyork, pp. 23-29.

26. Brahma, K. C., Pal, B. K. and Das, C. (2004): Study on Application of Petri Nets in Opencast Mining, 13th Int. Symp. on Mine Planning and Equipment Selection (MPES–2004), September 01-04, , held in Wroclaw, Poland, edited by A. A. Balkema, Rotterdam, pp. 01 -- 06.

27. Dey, K. and Pal, B. K. (2008): Ground Vibration – Unique Case Studies in Open Cast Mines, 6th Int. Conf. Case Histories in Geotechnical Engineering. Aug. 11--16, 2008, held in Univ. of Missouri, Rolla, USA, pp. 327 – 338.

28. Dowd, P. and Onur, A. (1992): Optimizing Open Pit Design and Sequence, Proceedings of 30th Int. Symp. on Application of Computer and Operation Research in the Mineral Industry, Tucson, Arizona, 7th -11th April, Kim Y. C. (Ed.), Littleton: Society for Mining, Metallurgy, and Exploration, First Edition, pp. 411-422.

29. Ghosh, A. K. (2004): Mine Equipment Selection using Failure Mode and Effects and Criticality Analysis, 13th Int. Symp. on Mine Planning and Equipment Selection (MPES–2004), September 01-04, , held in Wroclaw, Poland, edited by A. A. Balkema, Rotterdam, pp. 449 -- 454.

30. Jayanthu, S. (2011): Ground Vibrations Generated by Blasting, Nat. Sem. on Explosives and Blasting Techniques for Mining, Quarrying & Infrastructure Industry (EBTMQI), Feb. 18-19, 2011, held at KNIT, Surathkal, pp. 116-127.

31. Naik, H.K. and Patnaik, N.K. (1993): Application of Auto-CAD for Design and Planning of Dragline Mines, Indian Conf. on Computer applications in mineral Industry, held in Chennai, Tamilnadu, India, pp. 81-92.

32. Pal, B. K. (1994): Simulation Technique for the Performance Appraisal of Open-pit Mine Machinery, Proc. of the 3rd Int. Symp. on the Mine Planning and Equipment Selection, Oct. 18-20, 1994, held at Istanbul, Turkey, edited by A. A. Balkema, Rotterdam, pp. 501-507.

33. Ramajon, S. and Dimitrkopoulos, R. (2007): Stochastic Optimization of Long Term Production Scheduling for Open Pit Mines With a New Integer Programming Formulation, Ore Body Modeling and Strategic Mine Planning, Dimitrakopolous, R. (Ed), Carlton: Australasian Institute of Mining and Metallurgy, Spectrum Series, Vol. 14, First Ed. , pp. 353-360.

34. Samanta B, Kumar A, Bhattacherjee A, and Chatterjee S, (2007): Open Pit Mine design in Presence of Uncertainty Due to Ore Grade Modeling, Mineral Resource Engineering, Vol. 12, No. 4, P 241-257.

35. Snehamoy Chatterjee, Amina Lamghari and Roussos Dimitrakopoulos A. (2010): Two-Phase Heuristic Method for Constrained Pushback Design, Proceeding of the 4th Int. Conf. on Mining Innovation (MININ2010) Raul Castro, Xavier Emery, and Romke Kuyvenhoven (Ed.), Santiago, Chile, June, 2010.

36. Gershon, M. E. (1987), Heuristic Approaches for Mine Planning and Production Scheduling, International Journal of Mining and Geological Engineering, Vol. 5, pp. 1-13.

37. Kumral, M. and Dowd, P.A. (2002), Short-term Mine Production Scheduling for industrial Minerals using Multi-objective Simulated Annealing, Proceedings of 30th International Symposium on Application of Computers and Operations Research in the Mineral Industry, Phoenix, 25th -27th February, Bandopadhyay, S. (Ed.), Littleton: The Society of Mining, Metallurgy and Exploration, First Edition, pp. 13-19.

Appendix-A

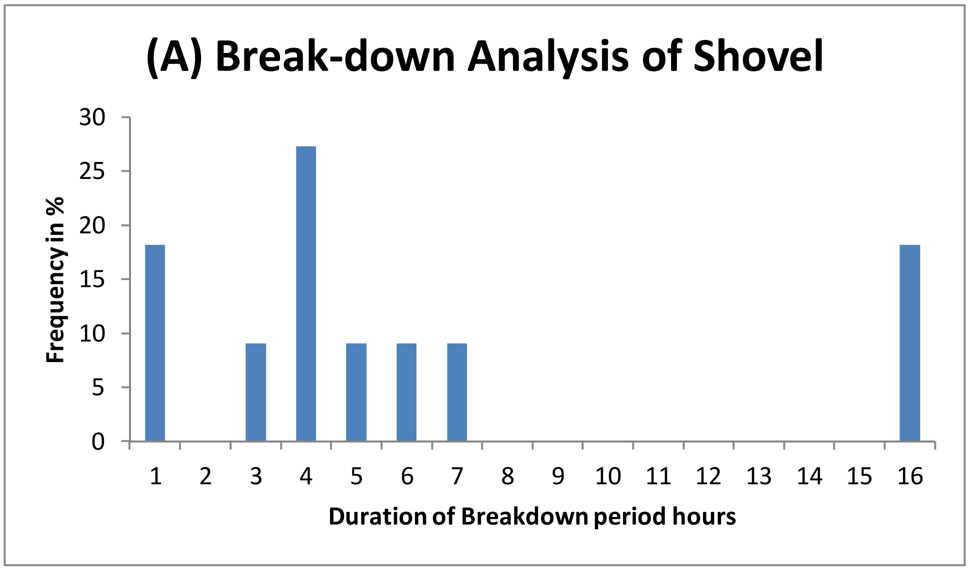

Fig A. 1 (A) Break-down analysis of shovel

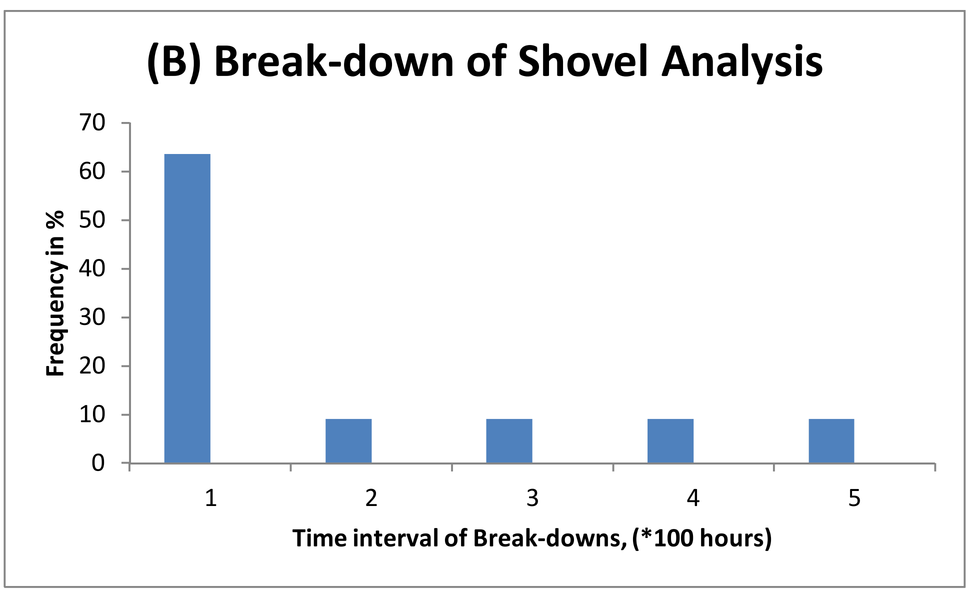

Fig A. 1 (B) Break-down analysis of shovel

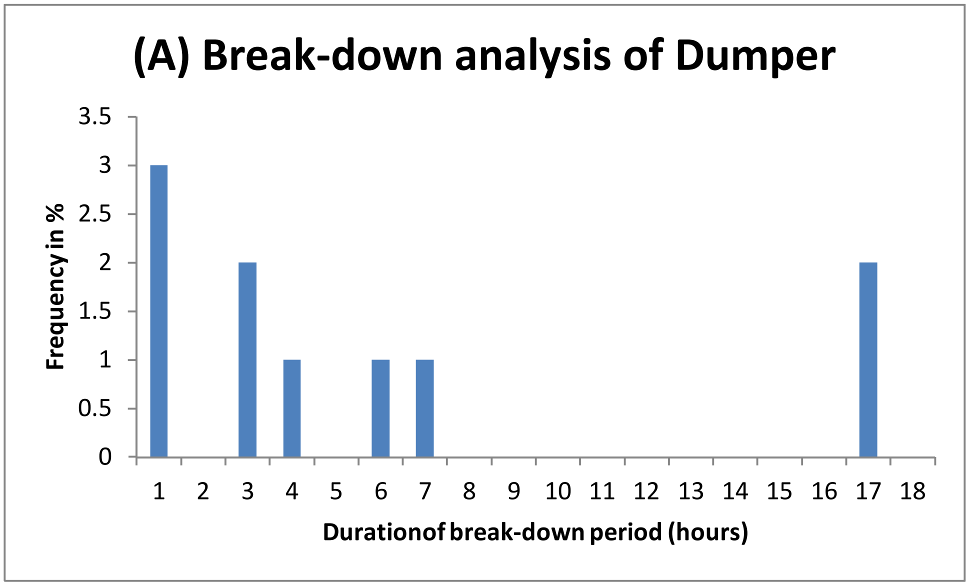

Fig A. 2 (A) Break-down analysis of Dumper

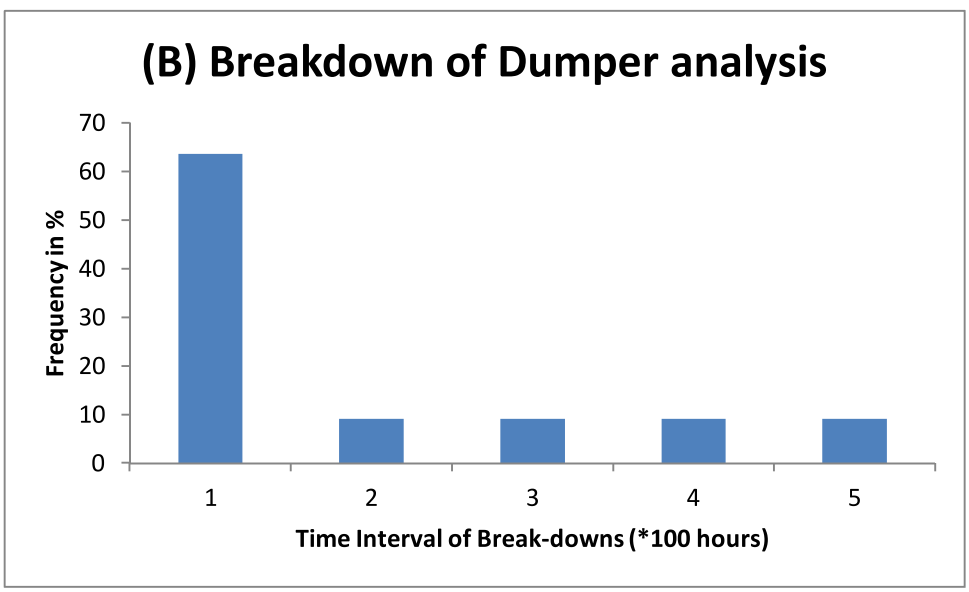

Fig A. 2 (B) Break-down analysis of Dumper

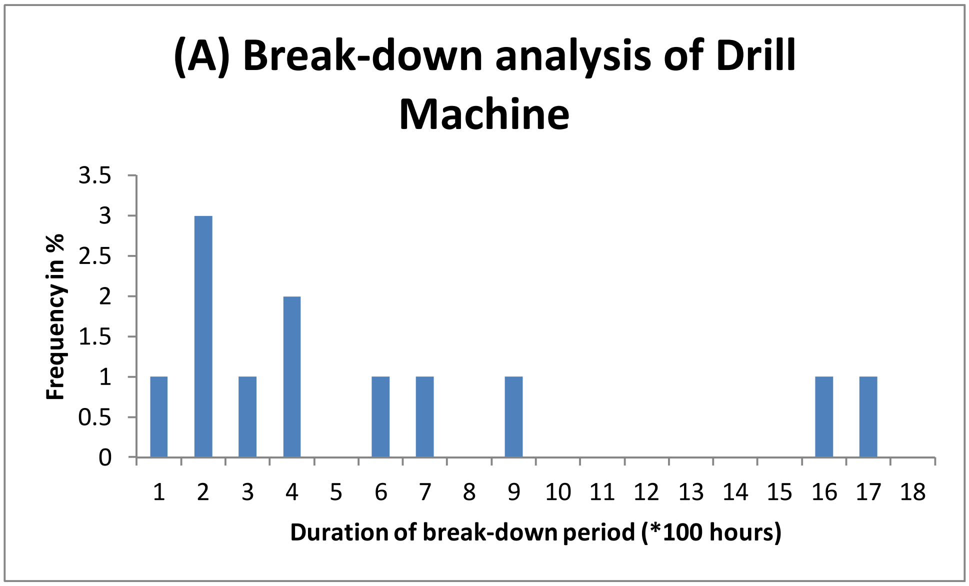

Fig A. 3 (A) Break-down analysis of Drill Machine

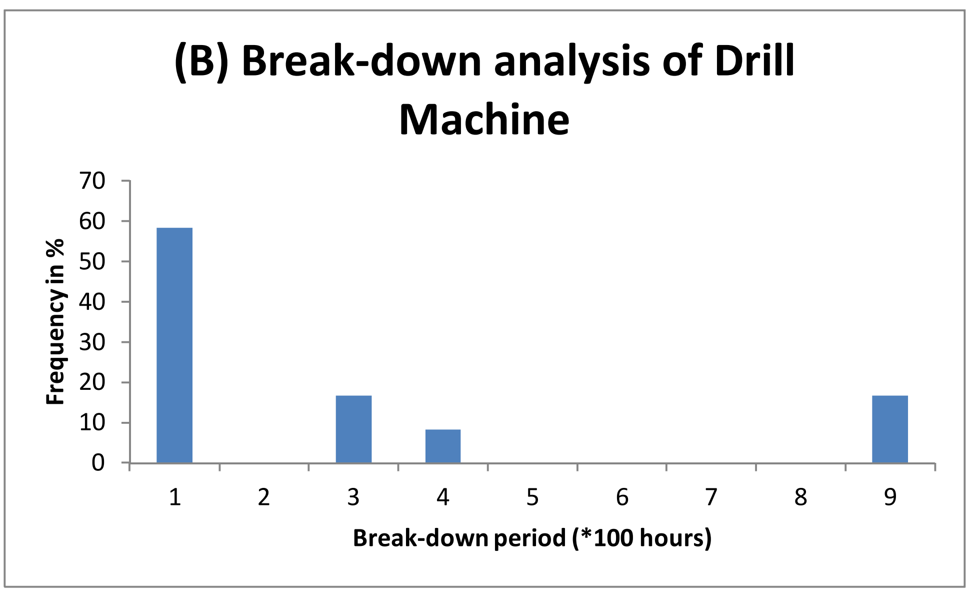

Fig A. 3 (B) Break-down analysis of Drill Machine

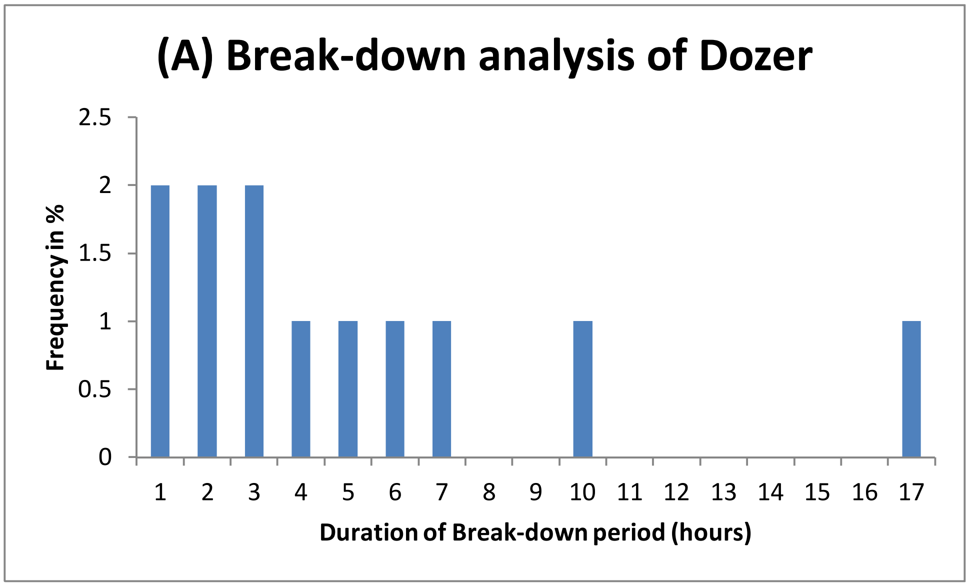

Fig A.4 (A) Break-down analysis of Dozer

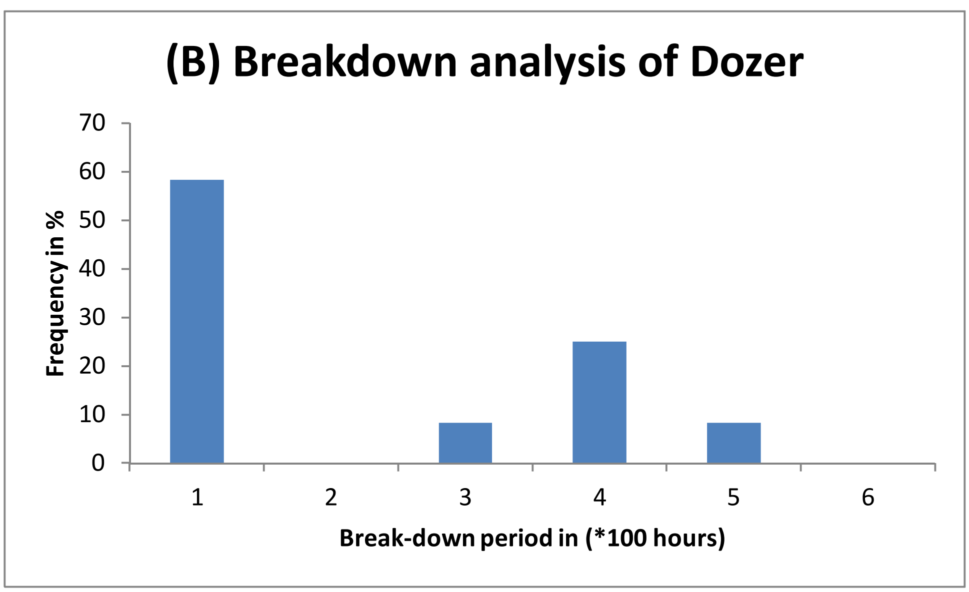

Fig A.4 (B) Break-down analysis of Dozer

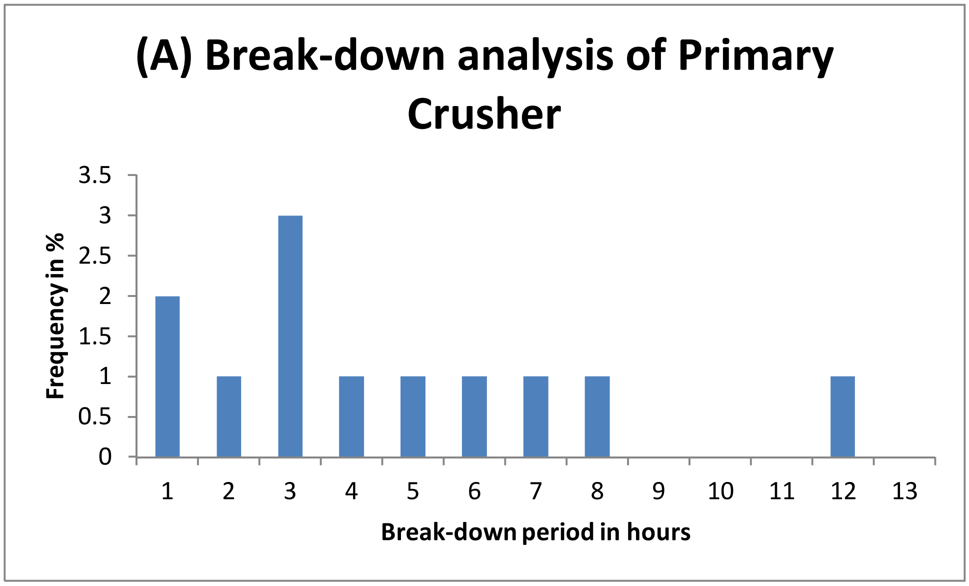

Fig A.5 (A) Break-down analysis of Primary Crusher

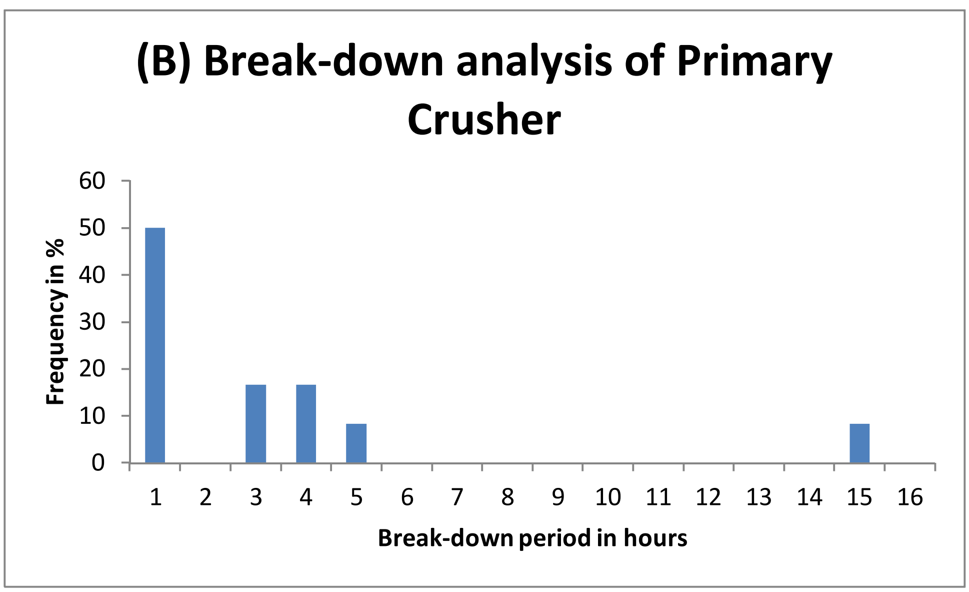

Fig A.5 (B) Break-down analysis of Primary Crusher

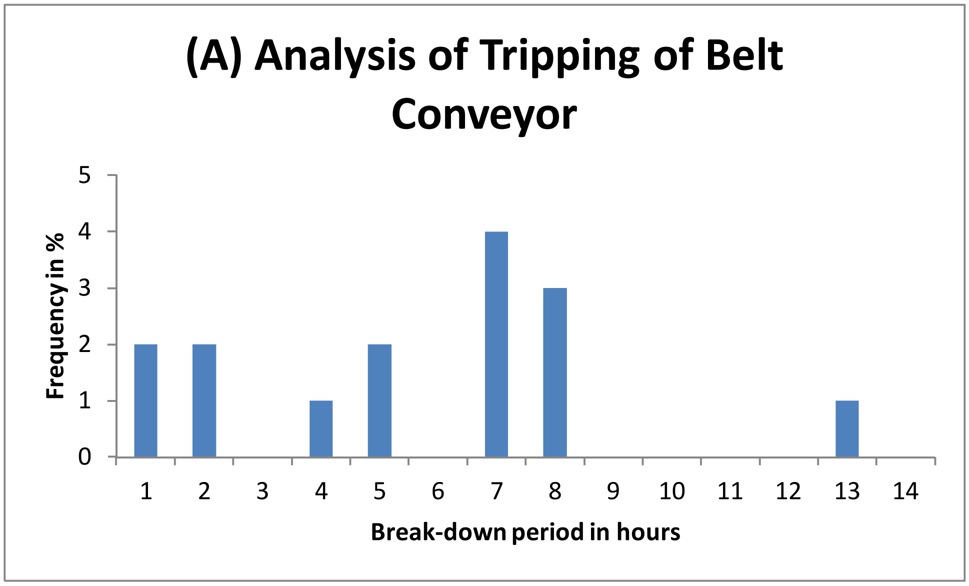

Fig A.6 (A) Analysis of Tripping of Belt Conveyor

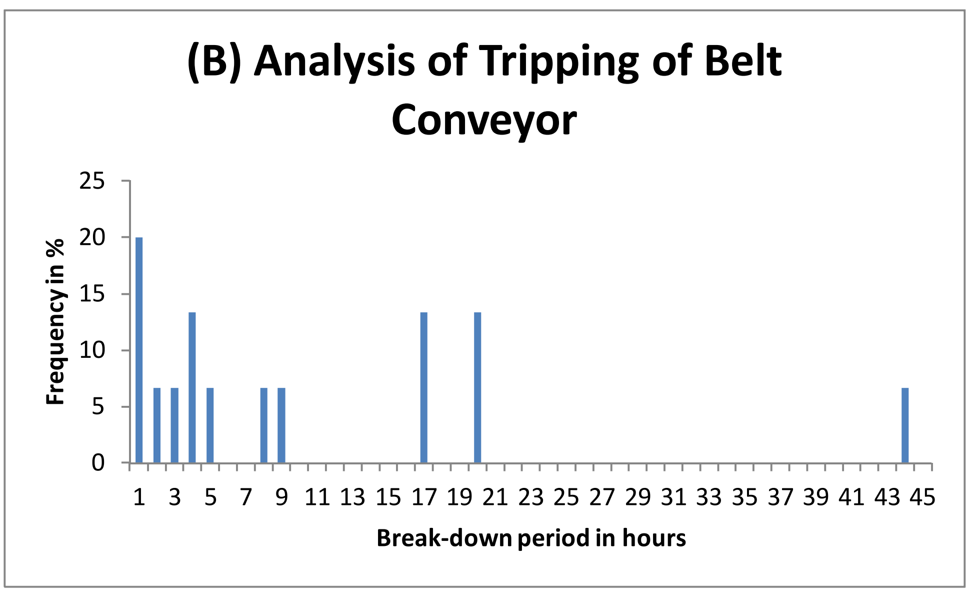

Fig A.6 (B) Analysis of Tripping of Belt Conveyor

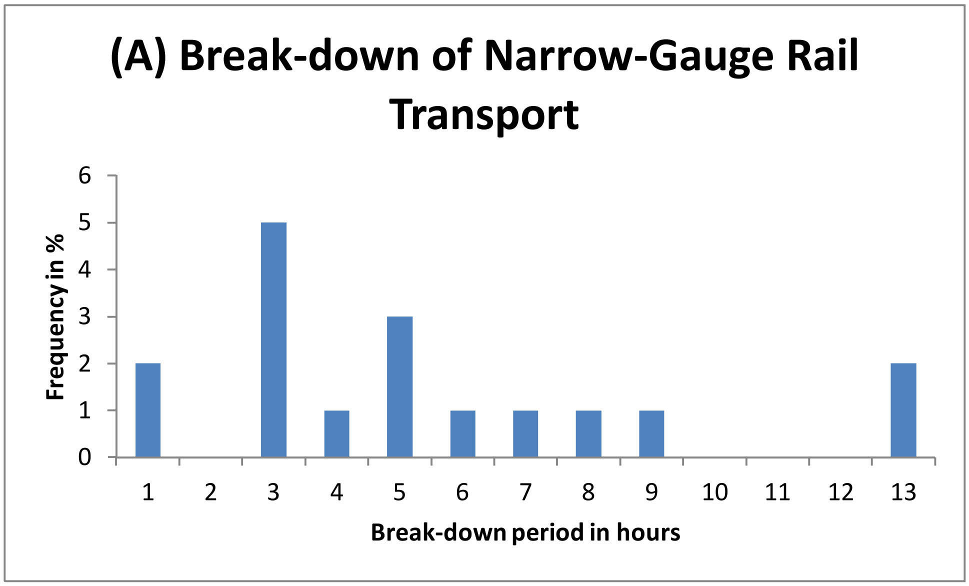

Fig A.7 (A) Break-down analysis of Narrow-Gauge Rail Transport

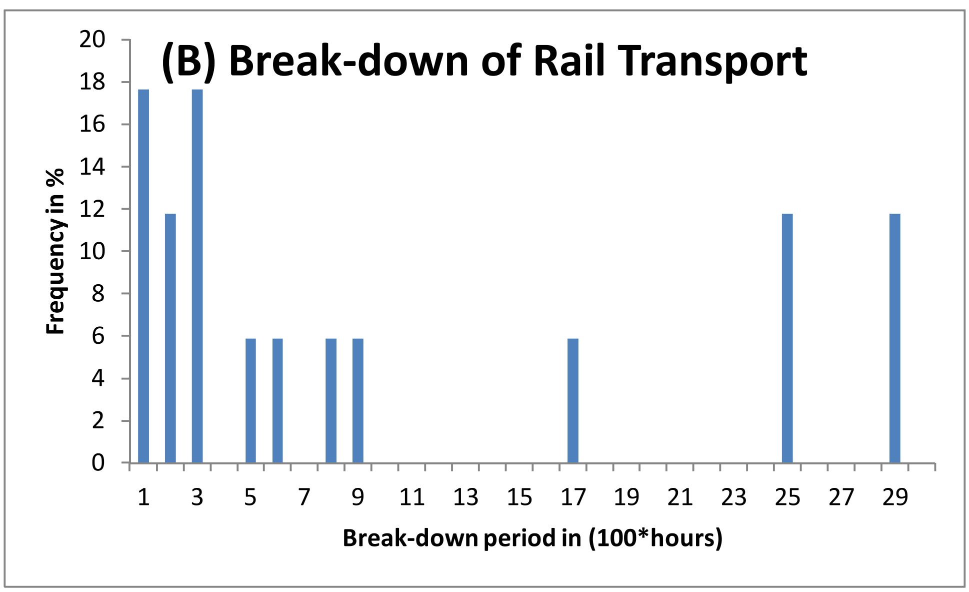

Fig A.7 (B) Break-down analysis of Narrow-Gauge Rail Transport

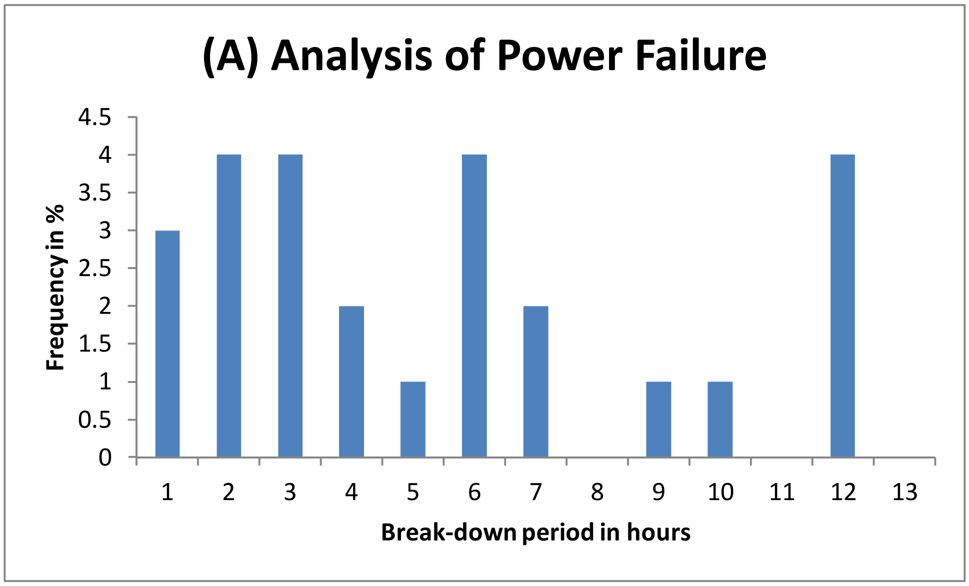

Fig A.8 (A) Analysis of Power Failure

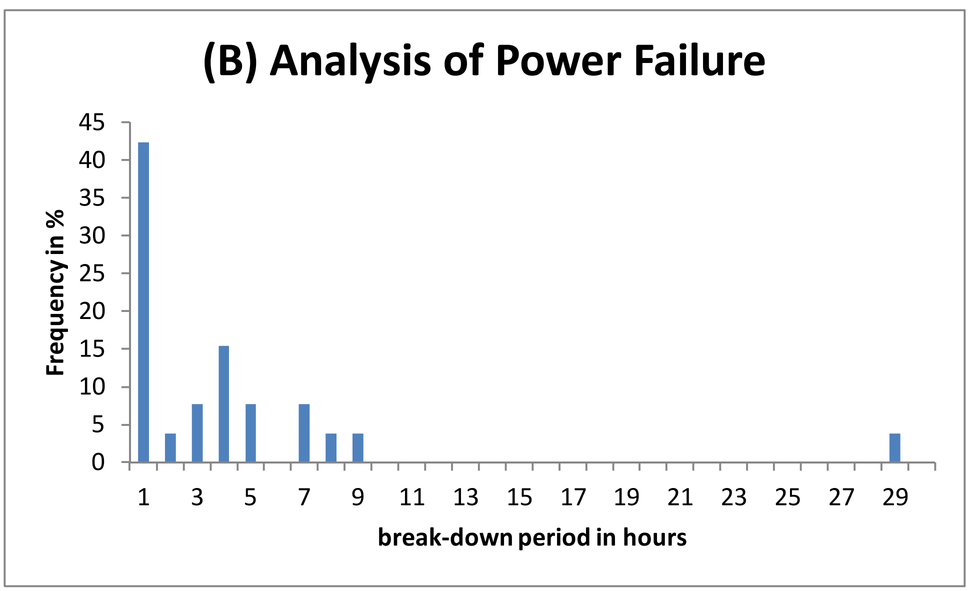

Fig A.8 (B) Analysis of Power Failure

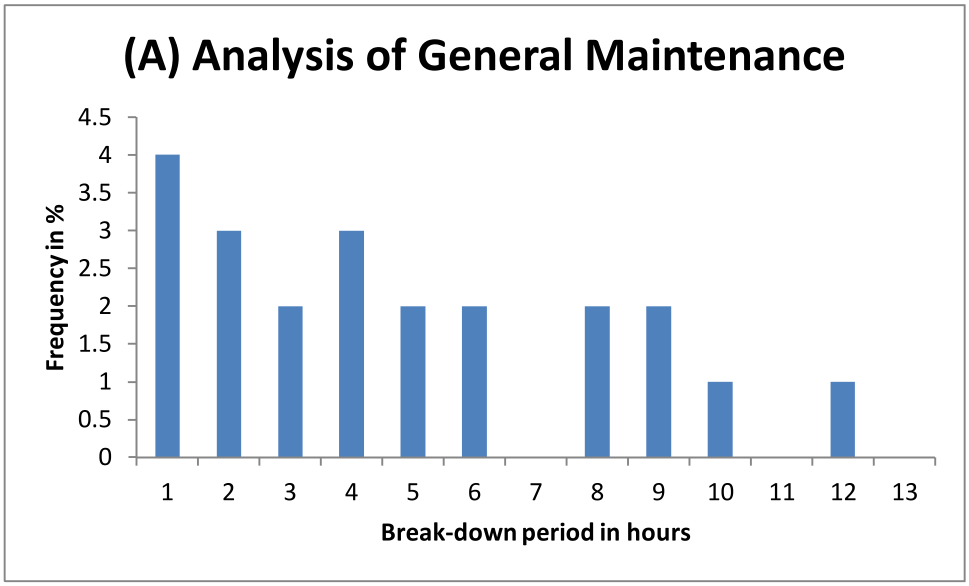

Fig A.9 (A) Analysis of General Maintenance

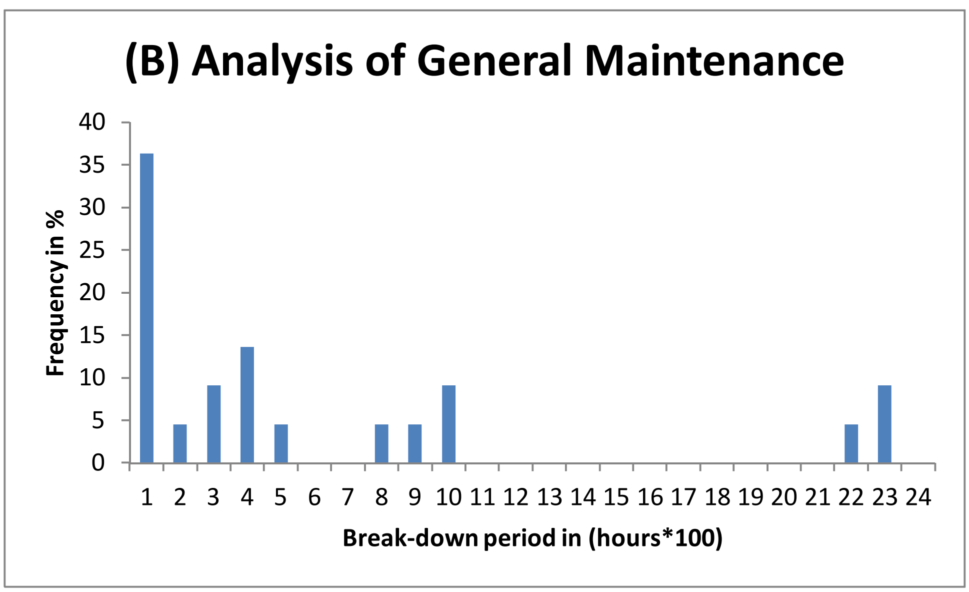

Fig A.9 (B) Analysis of General Maintenance

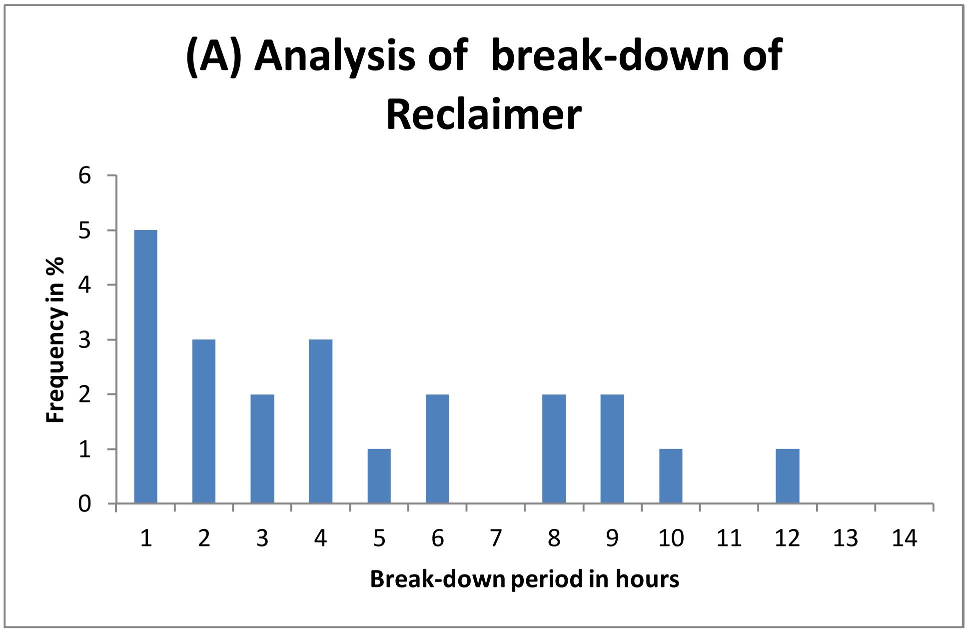

Fig A.10 (A) Break-down analysis of Reclaimer

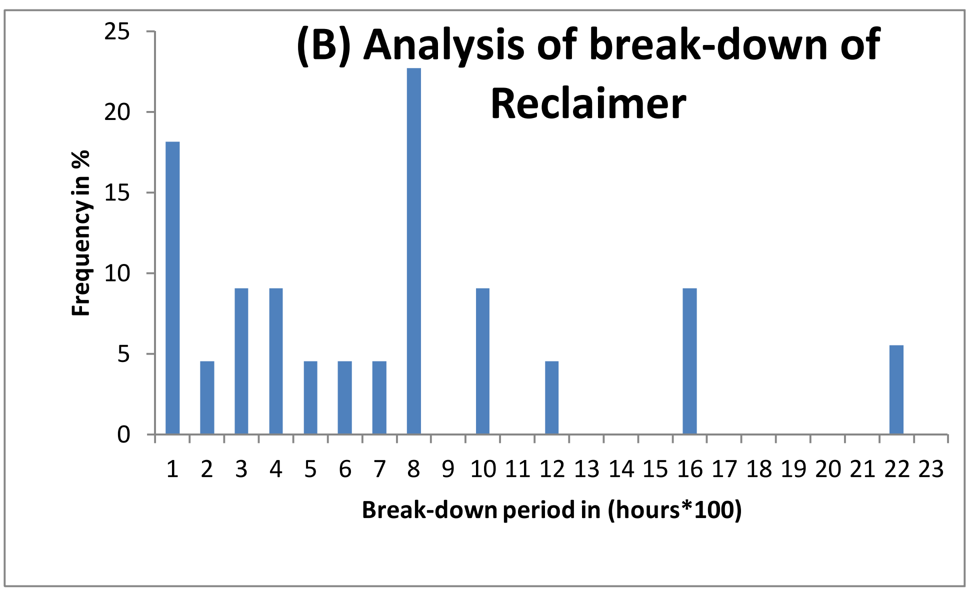

Fig A.10 (B) Break-down analysis of Reclaimer

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Thursday, 21 April, 2011 10:44 AM

From:
This sender is DomainKeys verified
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Add sender to Contacts
To:
"drbk Pal" <drbkpal2001@yahoo.com>

Dear Dr Pal,

Thank you for your e-mail and the paper titled "Use of Monte Carlo technique for production optimisation from large opencast mines - a case study". The paper has been accepted for publication in a forthcoming issue of the Journal of Mines, Metals & Fuels. However, I will let you know later in which issue this would be published on priority basis.

With warm regards,

P K Chanda
Executive Editor
JOURNAL OF MINES, METALS & FUELS
6/2 Madan Street
Kolkata 700 072
tel: 033 22126526
fax: 033 22126348
books@satyam.net.in
pradipchanda@yahoo.co.uk

--- On **Wed, 20/1/11, drbk Pal *<drbkpal2001@yahoo.com>*** wrote:

From: drbk Pal <drbkpal2001@yahoo.com>
Subject: PAPER
To: books@satyam.net.in
Cc: pradipchanda@yahoo.co.uk
Date: Wednesday, 20 January, 2011, 20:47

Dear Mr. Chanda,
My greetings to you from NIT, Rourkela. Enclosed please find the Full Manuscript of our Paper entitled "Use of Monte Carlo Technique for production Optimisation from Large Opencast Mines -- Case Study". Kindly acknowledge teh Receipt for the same.
With best wishes and regards,
DR. PAL

DR.B.K.PAL, PROFESSOR, DEPT. OF MINING ENGINEERING,
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA -- 769 008, INDIA.
PH. No.: +91-661-2462605/2463605; FAX:+91-661-2462999/2472926

USE OF MONTE-CARLO TECHNIQUE FOR PRODUCTION OPTIMISATION FROM LARGE OPENCAST MINES - CASE STUDY

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ABSTRACT

Globally the mineral sector is going through a technological revolution to cope with the downstream innovation. The advancement in technology has resulted in excavation of large volumes of natural resources from the mines. Mining industry is constantly search of higher levels of production with increased productivity and reduced cost. Besides the economics operating scale, the new dimension of development focused on automation, cleaner mining system, and increased utilization of assets by increasing machine performance. In this paper the probability of service (loading) facility of a shovel and arrival of a dumper are individually analyzed from their previous performances and then simulated on a simulation work-sheet using Monte-Carlo simulation technique and then computerized models are developed for optimization of production from a shovel-dumper combination in a large open-cast mines. The entire study was done in OCL Langibarna Limestone mines in Orissa.

INTRODUCTION

Globally the mineral sector is going through a technological revolution to cope with the downstream innovation. The advancement in technology has resulted in excavation of large volumes of natural resources from the mines. Mining industry is constantly search of higher levels of production with increased productivity and reduced cost. Besides the economics operating scale, the new dimension of development focused on automation, cleaner mining system, and increased utilization of assets by increasing machine performance [3].

After a mining company has got the lease of a mineral deposit the problem is then how to mine and process that deposit the best way. The principle problem is facing managers or engineers who must decide on mine plant size, equipment selection and long-range scheduling is how one can optimize a properly not only intense of efficiency but also as to project duration. For faster rate of production, mechanization at high degree is obvious. However, the charge of explosives plays an important role. The excess charge can create ground vibration, leading to damages to structures [5].

These machineries are very costly. So, unless they are properly matched reduction in production cost is very difficult. Increase in idle times of machineries leads to increase in production cost. In order to reduce the idle time or waiting time the number of machineries may be increased. Due to higher cost of machineries more investment is needed which ultimately contribute in higher production cost. So, unless you getting perfect matching optimum numbers of equipments reduction in production cost is impossible [1]. So, it is needed to analyze the operation of equipments considering their breakdown periods, repairing, maintenance, and preventive maintenance, availability of spare-parts, efficiency of operators and management philosophy etc. This study is based on use Monte-Carlo technique operation of shovel-dumper combination.

USE OF MONTE-CARLO TECHNIQUE FOR PRODUCTION OPTIMISATION FROM LARGE OPENCAST MINES

Many researchers have taken attempt to simulate the production optimization. Using of different mathematical models for mine production scheduling is extensively surveyed. The introduction of the concept of linear programming for optimization of mine production scheduling was made [9, 10]. They used linear programming to determine a feasible extraction sequence which ultimately maximized the total profits over the planning horizon. A dynamic cut-off grade strategy was applied to determinate between ore and waste in a mineral deposit and this cut-off change with time. The scheduling problem was formulated as a large scale linear programming problem considering governing constraints of the system and further by applying decomposition principle, the problem was decomposed into simple linear programming problem, called the master problem and set of sub-problem was relatively simple. The drilling operation in an opencast mine with double rod drilling provision has been considered for analysis and has been simulated [2]. Computer techniques were applied for design of dragline operation and its graphic representation for quick processing of databases was developed [6].

Also by using the first module of optimization calculations and construction of contours of mining operations in package regime we receive the most priority directions of moving of mining operations by working levels. It allows substantially decreasing time of a search of optimal contours of mining operations up to the end of planned period [4].

The second module is used for taking final decision in interactive regime and allows more adequate taking into account possible complex situations. It may be used in addition to operations of the first module or as independent apparatus for current and timely planning of mining operations [8].

For taking correct decision it is important to ensure a forenamed subsystems with reliable information about interaction of parameters and indexes of operation of opencast in different mining-technical and technological conditions with the help of spatial recognizing algorithm and formulae [7].

DESCRIPTION OF THE CASE STUDY MINES AND MACHINARIES

The OCL Langibarna Limestone mines is fully mechanized and located at northern Orissa, 10 km away from Rajgangpur town. The captive cement plant is at the same place. Here the massive limestone deposit is of anticline of "Gangpur Series". The mine is divided into six nos of different pits, marked as Pit No. -1, Pit No. -2,…..Pit No. -6. The bench height of the mines is around 10 m and ore is to waste ratio is 1:1. The targeted production is 10000 MT per day but due to some constraints present production is 6000-7000 MT per day. The machineries used in the mines are Drill machine: model ROCL-6 Make Atlas Cop co; Dozer: Model D 155, 320 HP, Make Komatsu; Road grader; BEML Haul pack Dumper: of 35 MT & 50 MT; Hydraulic shovels: of 4.5 cu m. & 6.5 cu m. of bucket capacity, Make TATA Hitachi, Model PC 1250; Road Roller:10 MT; Explosive Van: 8 MT capacity; Fuel Tanker: 10 KL; water sprinkler 10KL, 18KL and 22KL; Primary crushers: 400 TPH and 1600 TPH, of L&T make; Stalker cum reclaimer: 1200 TPH of China make; Belt conveyor: Transporting from crusher to cement plant around 10 km long; Also Narrow Gauge Loco: Transport from crusher to cement plant etc.

USE OF MONTE CARLO SIMULATION TECHNIQUE IN PRODUCTION OPTIMISATION

Simulation is a numerical technique for conducting experiments that involves certain types of mathematical and logical relationship necessary to describe the behavior and structure of a complex real world system over extended period of time. From definition it is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior (within the limit imposed by a criterion or a set of criteria) for the operation of the system. [7]. Using the simulation we can introduce the constants and variables related to the problem, set up the possible courses action and establish criteria which act as measures of effectiveness. The probability of service (loading) facility of a shovel and arrival of a dumper are individually analyzed from their previous performances and then simulated on a simulation work-sheet using Monte-Carlo simulation technique and then computerized models are developed for optimization of production from a shovel-dumper combination in a large open-cast mine. The entire study was done in OCL Langibarna Limestone mines in Orissa.

Table 1: Specification for Operating Cost of Shovel and Dumper

Model/make of machine	TATA HITACHI Hydraulic Shovel	BEML Dumper
Model	PC - 1250	Haulpak
Bucket capacity	6.5 cu m	50 MT
Cost of the machine	2.5 crore	1.25 crore
Life of the machine	8 years	8 years
e) Depreciation cost	Avg. 12% each year	Avg. 12% each year
f) Fuel cost	75 lits per hour	30 lits per hour
g) Maintenance & spare parts	20% of depreciation cost	20% of depreciation cost
h) Operators & helpers wages	Rs. 100/- per hour (say)	Rs. 50/- per hour (say)
Effective working hours in 2 shifts per day	10 hours per day	10 hours per day
Working days in a year	300 days	300 days

CALCULATION OF OPERATING COST OF SHOVEL:

Depreciation cost = 12% (of investment cost = 1.75 crore) Avg. per year = 2.5 * 0.12 = Rs. 30.00 lakh per year i.e. 3000000/300 = Rs. 10000 per day = Rs. 1000/- per hour.

Fuel cost (HSD Oil) 75 liters per hour @ Rs. 40/- per lit. = Rs 3000/- per hour.

Maintenance & spare parts cost = 20% of depreciation cost = Rs. 200/- per hour.

Operators & helpers wages = Rs. 100/- (Approx.) per hour.

So, total operating cost for shovel = a) + b) + c) + d) = Rs.(1000 + 3000 + 200 + 100) = Rs. 4300/- per hour.

CALCULATION OF OPERATING COST OF DUMPER:

Depreciation cost = 12% (of investment cost = 1.25 crore) Avg. per year = 1.25 * 0.12 = Rs. 15.00 lakh per year i.e. 1500000/300 = Rs. 5000 per day = Rs. 500/- per hour.

Fuel cost 30 liters per hour @ Rs. 40/- per lit. = Rs 1200/- per hour.

Maintenance & spare parts cost = 20% of depreciation cost = Rs. 100/- per hour.

Operators & helpers wages = Rs. 50/- (Approx.) per hour.

So, total operating cost for shovel = a) + b) + c) + d) = Rs.(500+1200 + 100 + 50) = Rs. 1850/- per hour.

Now at Pit No-6 haul pack dumpers of 50 MT capacities are loaded with ROM for crusher feeding with a shovel of 6.5 cu m bucket capacity, which has the following characteristics:

The mean arrival rate of dumpers and mean loading time are (lead distance 2 km avg. @ speed 20-25 km per hour of the dumpers) 6.2 minutes 5.5 minutes respectively. The time between arrival and its (cycle time) loading varies from 1 minute to 7 minutes. The arrival and loading time distribution are given below:

Table 2: Arrival and Loading Time Distribution

Time (minutes)	Arrival (probability)	Loading (probability)	Time (minutes)	Arrival (probability)	Loading (probability)
1 – 2	0.05	0.10	4 – 5	0.25	0.20
2 – 3	0.20	0.20	5 – 6	0.10	0.10
3 – 4	0.35	0.40	6 - 7	0.05	--

The queuing process starts at 7:00 A.M. and the calculation done up to 8:00 A.M. i.e. for 1 (one) hour interval only. An arrival of dumper immediately moves to spot for availing the loading facility if the shovel is idle. On the other hand, if the shovel is busy the dumper will wait on the queue. Dumpers are loaded on the first come first serve basis. Using Monte-Carlo simulation technique from the given frequency distribution of arrival and loading times, the probabilities and cumulative probabilities are first worked out as shown below. These then become the basis for generating arrival and loading times in conjunction with a table of random numbers:

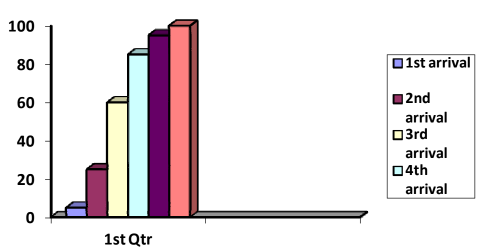

Figure 1: Cumulative probabilities vs time between interval (minutes)

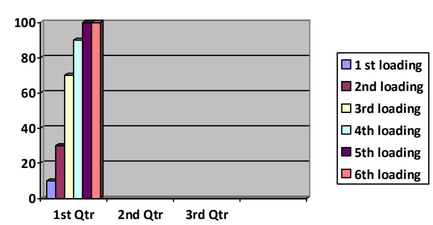

Figure 2: Cumulative probabilities vs loading time (minutes)

Time between arrival (minutes)	Cumulative probability

1-2	0.05
2-3	0.25
3-4	0.60
4-5	0.85
5-6	0.95
6-7	1.00

Table 3: Cumulative probability

Loading Time (minutes)	Cumulative probability
1-2	0.10
2-3	0.30
3-4	0.70
4-5	0.90

Table 4: Cumulativ

As we have to use random number table, first of all we allot the random numbers to various intervals as shown in the table below.

Table 5: Random number coding

Inter arrival time(minute)	Probability	RN allotted
1-2	0.05	00-04
2-3	0.20	05-24
3-4	0.35	25-59
4-5	0.25	60-84
5-6	0.10	85-94

Table 6: Random number coding

for loading time

6-7	0.05	95-99
Inter arrival time(minute)	Probability	RN allotted
1-2	0.05	00-04
2-3	0.20	05-24
3-4	0.35	25-59
4-5	0.25	60-84

The random number develop are related to the c[illegible] loading time. The first random number of arrival time is 31. This number lies between 25 and 59 and indicates a simulated arrival time of 3 minutes. All simulated arrival and loading times have been worked out in a similar fashion. After generating the arrival and loading times from a table of random numbers, the next step is to list the arrival time in the appropriate Colum. The first arrival comes in 3 minutes after the starting time. This means the shovel waited for 3minutes initially. It has been shown under the Colum-waiting time: shovel. The first random number of loading time is 79. This number lies between 70 and 89. So, the simulated loading time for the first arrival is 4 minutes which result in the loading begins at 7:03 AM and completed in 7:07 AM. The next arrival comes at 7:08.

Table 7: Simulation Work-Sheet

RN	Inter arrival time	Arrival time(AM)	Loading begins (AM)	RN	Loading		Waiting time (min)		
					Time (min)	Ends (AM)	Shovel	Dumper	Line length
31	3	7:03	7:03	35	3	7:06	3	-	-
65	4	7:07	7:07	78	4	7:11	1	-	-

03	1	7:08	7:11	09	1	7:12	-	3	-
79	5	7:13	7:13	47	3	7:16	1	-	-
24	3	7:16	7:16	51	4	7:20	-	-	-
36	3	7:19	7:20	89	5	7:24	-	1	1
88	5	7:24	7:24	13	2	7:26	-	-	-
45	4	7:28	7:28	36	3	7:31	2	-	-
04	2	7:30	7:31	74	4	7:35	-	1	1
16	3	7:33	7:35	61	4	7:39	-	2	1
65	4	7:37	7:39	63	4	7:43	-	2	1
55	4	7:41	7:43	11	2	7:45	-	4	1
96	6	7:47	7:47	02	1	7:48	2	-	-
02	1	7:48	7:48	42	3	7:51	-	-	-
71	4	7:52	7:52	59	4	7:56	1	-	-
52	4	7:56	7:56	05	1	7:57	-	-	-
13	2	7:58	7:58	08	2	8:00	1	-	-
	58				50		11	13	5

The following information can be obtained from the above simulation work-sheet based on the period of one hour only. The cost of using additional shovel and dumper are shown in Table 8 & Table 9.

Table 8: Cost Comparison with additional Shovel

One hour period	Cost with one shovel	Cost with two shovels
Dumper waiting time 13 minutes * Rs 1850/- per hour	Rs 401/-	Nil

Shovel cost	Rs 4300/-	Rs 8600/-
Total cost for one hour period	Rs 4701/-	Rs 8600/-

Table 9: Cost Comparison with additional Dumper

One hour period	Cost with existing dumper	Cost with one additional dumper
Shovel waiting time(11 minutes *Rs 4300/- per hour)	Rs 788/-	Nil
Dumper's cost	N	N + 1850
Total cost of one hour period	N + 788/-	N + 1850

RESULTS:

The following information can be obtained from the above simulation work sheet based on the period one hour only.

e) Average Queue Length = No of dumpers in the waiting line / No
f) Average Waiting Time for the Dumper before Loading = Dumper waiting time / No of Arrivals = 13/17 = 0.76
g) Average Loading Time = Total Loading Time/No of Arrival = 50 / 17 = 2.94 minutes
h) Time a Dumper Spend in the System = Average Loading Time + Average Waiting Time before Loading = 2.94 + 0.76 = 3.70 minutes

CONCLUSION:

Simulation Work-Sheet developed in this problem also states that if one or more dumper is added in the system. There is no need for a dumper to wait in the queue. But, before effecting any decision, the cost of having an additional shovel has to compare with the cost due to dumper waiting time. This is shown in Table 8. So, we see clearly that for one hour period dumper loss 13 minutes for which provide of one additional shovel will not be a wise decision. The same way we can calculate the cost of one additional dumper which is to be compared with time loss due shovel waiting time. This is shown in Table 9. Also addition of one more dumper is costlier than the no of existing dumper with shovel loss due to waiting time. Hence the selection of equipment is optimum with this simulation work sheet. Now, it depends on management's philosophy that if they want to calculate maximum loss due to shovel and dumper is manageable but at the same time the primary crusher will be idle, and the entire transporting system will be idle, etc these will cost drastic production loss. So, one more shovel or dumper or both are to be added in the system whichever is less though it is not economic, but in greater sense it will help to continue the entire system and much economical.

REFERENCES:

1. Brahma, K. C., Pal, B. K. and Das, C. (2004): Study on Application of Petri Nets in Opencast Mining, 13th Int. Symp. on Mine Planning and Equipment Selection (MPES–2004), September 01-04, , held in Wroclaw, Poland, edited by A. A. Balkema, Rotterdam, pp. 01 -- 06.
2. Dey, K. and Pal, B. K. (2008): Ground Vibration – Unique Case Studies in Open Cast Mines, 6th Int. Conf. Case Histories in Geotechnical Engineering. Aug. 11--16, 2008, held in Univ. of Missouri, Rolla, USA, pp. 327 – 338.
3. Dowd, P. and Onur, A. (1992): Optimizing Open Pit Design and Sequence, Proceedings of 30th Int. Symp. on Application of Computer and Operation Research in the Mineral Industry, Tucson, Arizona, 7th -11th April, Kim Y. C. (Ed.), Littleton: Society for Mining, Metallurgy, and Exploration, First Edition, pp. 411-422.
4. Ghosh, A. K. (2004): Mine Equipment Selection using Failure Mode and Effects and Criticality Analysis, 13th Int. Symp. on Mine Planning and Equipment Selection (MPES–2004), September 01-04, , held in Wroclaw, Poland, edited by A. A. Balkema, Rotterdam, pp. 449 -- 454.
5. Jayanthu, S. (2011): Ground Vibrations Generated by Blasting, Nat. Sem. on Explosives and Blasting Techniques for Mining, Quarrying & Infrastructure Industry (EBTMQI), Feb. 18-19, 2011, held at KNIT, Surathkal, pp. 116-127.
6. Naik, H.K. and Patnaik, N.K. (1993): Application of Auto-CAD for Design and Planning of Dragline Mines, Indian Conf. on Computer applications in mineral Industry, held in Chennai, Tamilnadu, India, pp. 81-92.
7. Pal, B. K. (1994): Simulation Technique for the Performance Appraisal of Open-pit Mine Machinery, Proc. of the 3rd Int. Symp. on the Mine Planning and Equipment Selection, Oct. 18-20, 1994, held at Istanbul, Turkey, edited by A. A. Balkema, Rotterdam, pp. 501-507.
8. Ramajon, S. and Dimitrkopoulos, R. (2007): Stochastic Optimization of Long Term Production Scheduling for Open Pit Mines With a New Integer Programming Formulation, Ore Body

Modeling and Strategic Mine Planning, Dimitrakopolous, R. (Ed), Carlton: Australasian Institute of Mining and Metallurgy, Spectrum Series, Vol. 14, First Ed. , pp. 353-360.

9. Samanta B, Kumar A, Bhattacherjee A, and Chatterjee S, (2007): Open Pit Mine design in Presence of Uncertainty Due to Ore Grade Modeling, Mineral Resource Engineering, Vol. 12, No. 4, P 241-257.

10. Snehamoy Chatterjee, Amina Lamghari and Roussos Dimitrakopoulos A. (2010): Two-Phase Heuristic Method for Constrained Pushback Design, Proceeding of the 4th Int. Conf. on Mining Innovation (MININ2010) Raul Castro, Xavier Emery, and Romke Kuyvenhoven (Ed.), Santiago, Chile, June, 2010.

NOMENCLATURES:

AT = Arrival Time

LAT = Last Arrival Time

IAT = Inter Arrival Time

IATSR = Inter Arrival Time Sub-Routine

ILT = Inter Loading Time

ILTSR = Inter Loading Time Sub-Routine

CLET = Current Load End Time

PLET = Previous Load End Time

LBT = Load Begin Time

DWT = Dumper Wait Time

SWT = Shovel Wait Time

TDWT = Total Dumper Wait Time

TSWT = Total Shovel Wait Time

ADWT = Average Dumper Wait Time

AILT = Average Inter Loading Time

RN1 = Random Number 1

RN2 = Random Number 2

ADWT = TDWT/Count

IATSR (RN1=IAT) = IASR/

AILT = TILT/Count

ILTSR (RN2=ILT) = ILTSR/

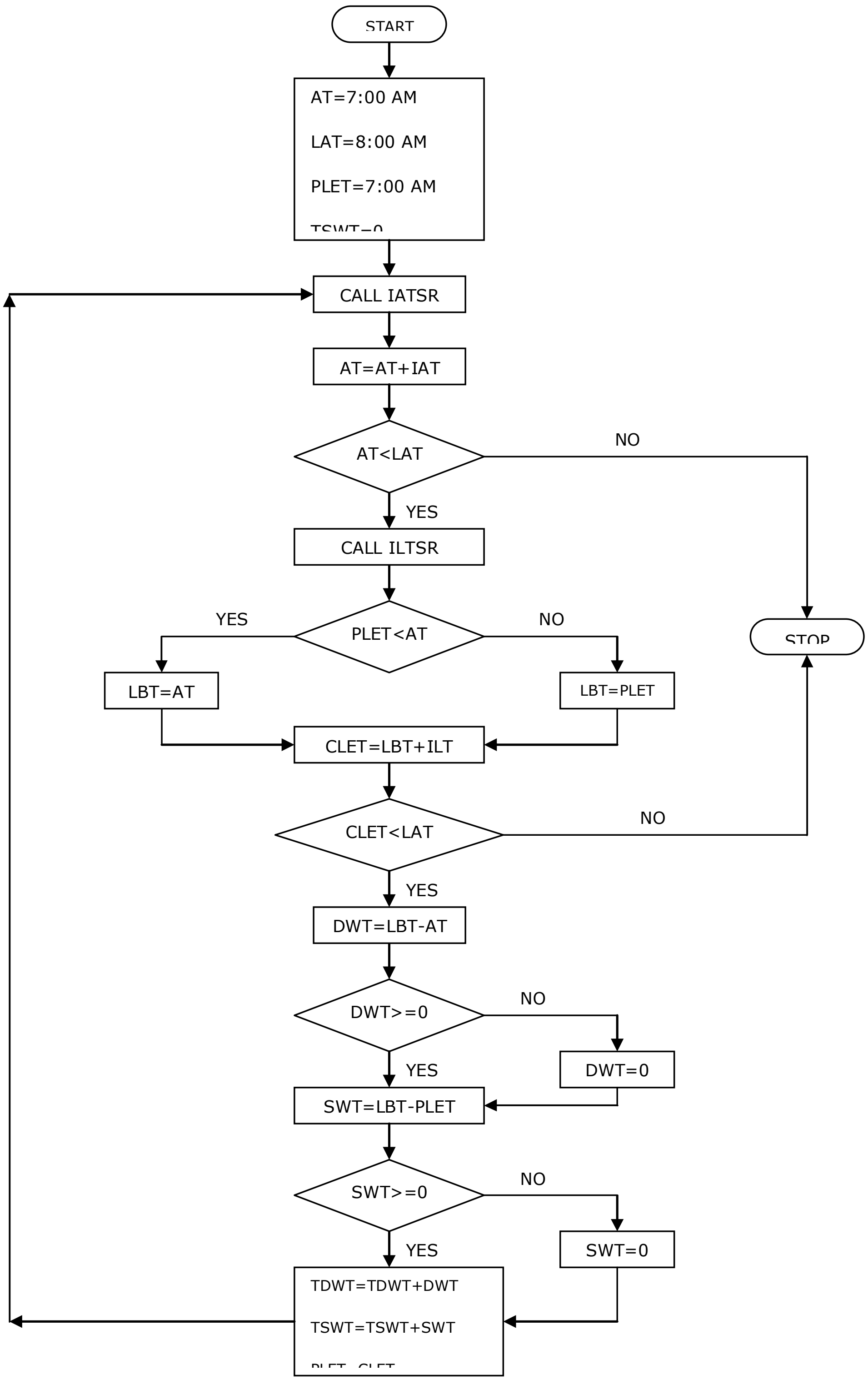

Fig. 3: Flow Chart Showing Simulation Work-Sheet

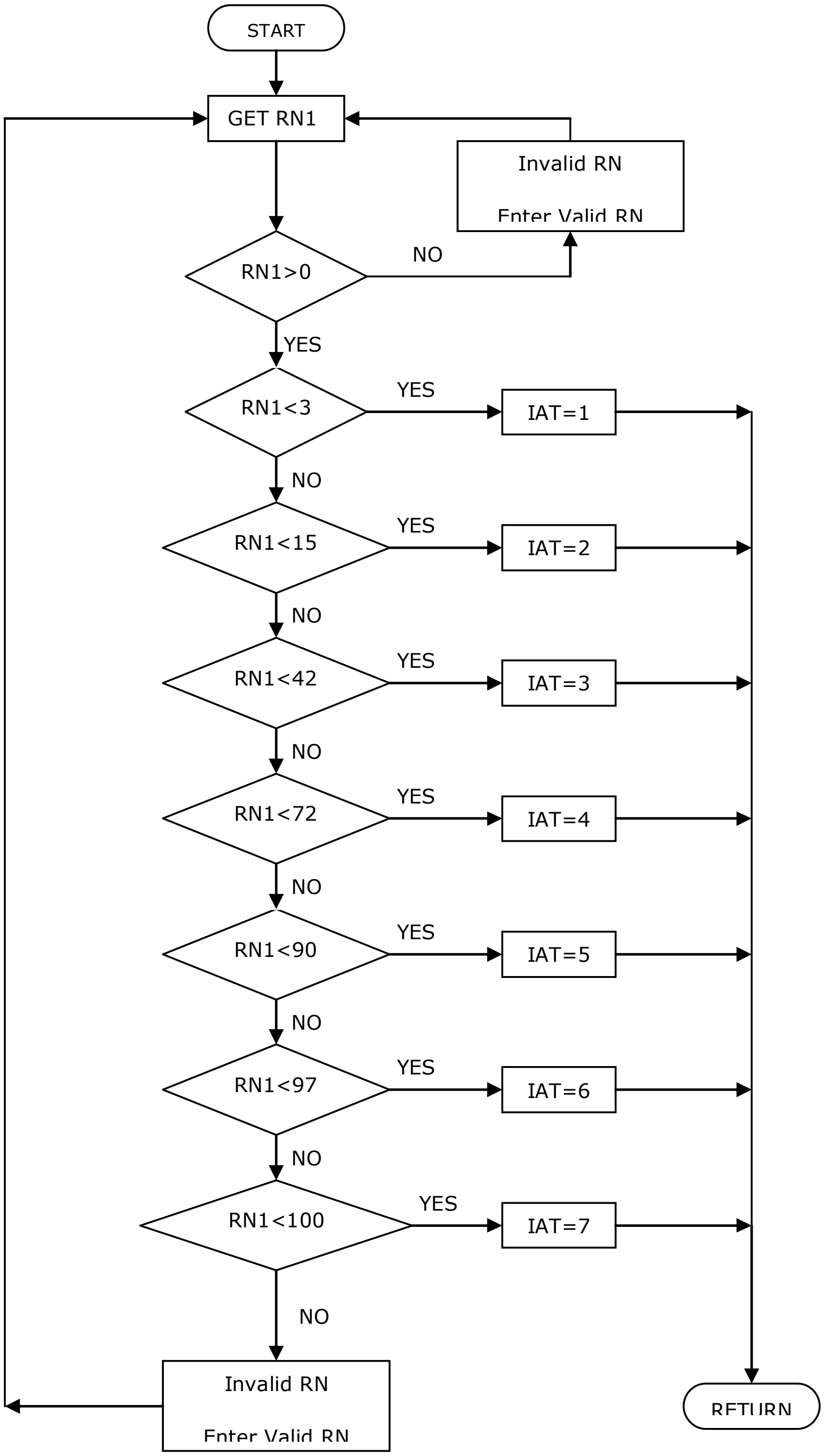

Fig. 4: Flow Chart Showing Sub-Routine Inter Arrival Time

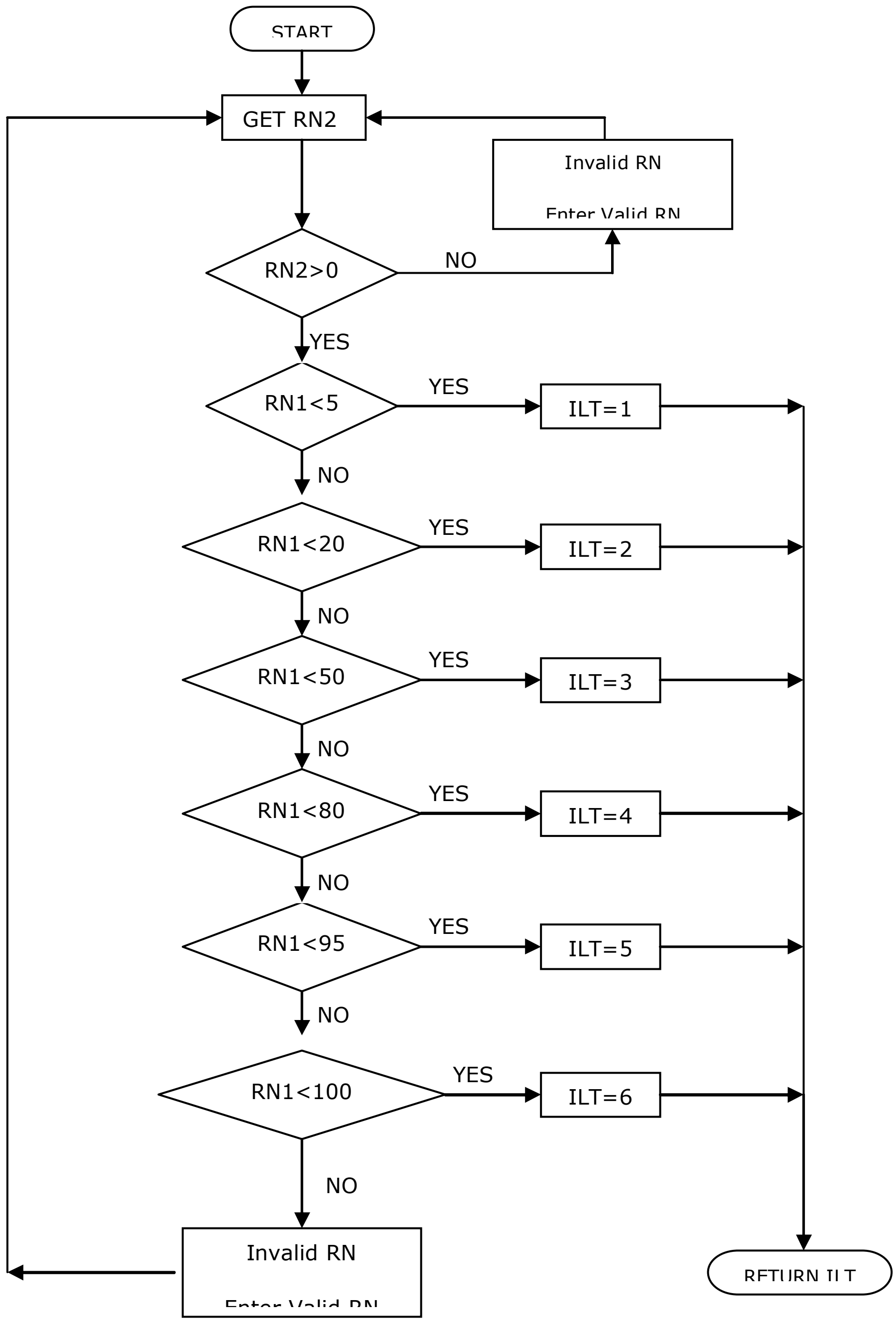

Fig. 5: Flow Chart Showing Sub-Routine Inter Loading Time