Development of a Decision Support System and Performance Optimization for a Rock Gold Processing Plant Using a Genetic Algorithm

Priya Chaudhary, Shikha Bansal

Abstract—**This study introduces a proposed decision support system (DSS) for the rock gold processing plant, which employs a genetic algorithm (GA). A gold plant comprises many engineering components, such as a jaw crusher, belt conveyor, ball mill, centrifugal concentrator, shaking table, and gold furnace machine. The rock gold processing facility studied consists of six subsystems, each of which can be in one of three states: fully functional, working at a reduced capacity, or experiencing failure. An exponential distribution accounts for potential repairs and failures in the probabilistic framework that defines the problem. Designing differential equations based on the Markov birth-death process. The steady-state availability of the gold plant is then ascertained by solving these equations and applying normalizing conditions. Following the implementation of a genetic algorithm, the availability optimization of the rock gold processing plant has been computed, yielding the optimal level of availability. Utilizing a genetic algorithm, a decision support system is employed to determine the repair priority for the subsystems of a gold plant. A decision support system is advantageous for making timely maintenance and repair decisions. The results of this study provide significant advantages for future maintenance planning and enhancing the performance of the relevant unit.**

Index Terms—**Performance, Markov modeling, probabilistic approach, rock gold processing plant, genetic algorithm, mutation.**

I. INTRODUCTION

IN today's globalized economy, achieving high productivity is essential for every industrial system to remain competitive in the international market. Process industries have complicated setups that are made to handle large amounts of bulky items all the time. Usually, these are limited products that are made in huge quantities. Process industries such as gold, coal, metal, and diamond confront significant challenges in achieving high productivity while minimizing the number of parallel units, losses, and failure costs. Therefore, ensuring reliable operation in these businesses is crucial, which can be achieved by implementing corrective maintenance actions at the appropriate location and time. This work proposes a decision support system (DSS) for the gold plant, utilizing a genetic algorithm (GA). Gold mining has been an ancient practice for millennia, with the techniques for extracting gold from rock gradually improving. Alluvial deposits yielded gold discoveries in ancient times. However, once the surface As reserves became exhausted, miners were required to excavate deeper into the ground. Gravity-based separation techniques came after manually pulverizing the rock in the initial stage. In the late 19th century, the cyanidation method emerged, bringing about a revolutionary change in gold processing. This technique enabled the extraction of gold from ores with poor levels of quality. Modern techniques include carbon-in-pulp (CIP) and carbon-in-leach (CIL), which adsorb gold onto activated carbon. Advanced methods such as crushing, grinding, gravity separation, and cyanidation are employed in large-scale gold processing plants to extract gold from the rock while minimizing environmental harm. The study's findings are that numerous researchers have extensively researched the behavior analysis of numerous units operating in various process sectors utilizing a probabilistic methodology. System reliability analysis can be conducted using deterministic or probabilistic approaches. Previously, determinism characterized practical procedures, and a few of these techniques are still in use today. Discussed the leaf spring manufacturing factory and screw manufacturing plant utilizing mathematical modeling and availability analysis to optimize production processes, such as material utilization, efficiency, and equipment downtime. This study optimizes operational efficiency by reducing downtime, maximizing productivity, and ensuring adherence to quality standards, all while fulfilling the demands of users[1,12]. Discussed a performance study that assesses the efficacy of a case-based reasoning (CBR) system in problem-solving by evaluating factors such as retrieval accuracy, adaptation quality, computational efficiency, scalability, and resilience. The text also examines the influence of similarity metrics, case representations, and adaptation strategies, offering valuable insights for enhancement [2]. The proposed Laplace methodology is a method in reliability engineering that is employed to examine failure rates and the probability of downtime in hydroelectric power facilities. This tool assists engineers in calculating essential reliability measures, optimizing maintenance timetables, and identifying crucial components to enhance dependability and operating efficiency [3]. The neural network method is employed to forecast reliability indicators in multi-state computer systems and steam turbine generator power plants. The model is trained using historical data and dependability measures, which helps implement preventive maintenance and make informed decisions. Boolean function approaches represent intricate relationships, improve models, and optimize power plant operations [4,11]. The protocol provides an energy-efficient RNMDP for vehicular ad hoc networks, which alerts

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vehicles when they approach risk zones. The protocol prefers nodes distant from the sender to transmit messages, as well as flooding with less energy waste [5]. Gold ore processing simulators are computer tools that accurately replicate the complete sequence of operations involved in the processing of gold ore, starting from the first crushing stage and ending with the final refining stage. They assist engineers and operators in analyzing parameters to optimize efficiency and maximize profitability. These simulators also function as teaching aids, enabling people to become acquainted with plant operations and emergency protocols in a safe virtual setting. Also, analysis of the redundancy and availability of the BCHP system [6,8,14]. Employ mathematical equations, computational tools, and empirical data to optimize operating parameters and energy output while reducing resource use and environmental impact [7]. Discussed the novel Metaheuristic Scanning Genetic Algorithm (MSGA) optimizes wind and solar power-generating systems to improve dependability and efficiency. This algorithm reduces computing time by 85% compared to particle swarm optimization and 2% over the differential evolution optimization algorithm. MSGA excels at managing and forecasting power capacity in hybrid energy systems [9]. This study employs stochastic Petri net simulation to examine the dynamics of a wood industrial subsystem. Its objective is to optimize maintenance decisions and improve the efficiency and reliability of wood industrial processes. This is achieved by considering factors such as resource utilization, production rates, and maintenance requirements [10].

Evaluate the Gumble-Hougaard distribution approach employed to conduct reliability analysis in spirulina production and thresher facilities. It evaluates the duration of failures for crucial components, forecasting future performance and maintenance requirements. This aids in optimizing maintenance schedules, reducing downtime, and guaranteeing efficient functioning [13,22]. Optimized the gold processing stage in concentrator facilities, scientists employed sophisticated methodologies such as modeling, simulation, mineralogical analysis, and online optimization. To enhance efficiency and sustainability, they executed comprehensive examinations, incorporated a dissolution loop technique, and assessed a carbon-in-pulp gold recovery method [15,16,19]. The study uses an analytical selection method and a genetic algorithm to find the best support vector regression parameters for predicting system reliability. This leads to better prediction accuracy, convergence speed, and resilience [17]. Implant the GA-based problem-specific genetic algorithm that optimizes series-parallel systems with k-out-of-n: G subsystems with minimal redundancy types, component choices, mixing, and managing system-level reliability, cost, and weight constraints [18]. Penalty functions and advanced optimization methods increase network reliability and efficiency under difficult restrictions when hybridized with metaheuristic algorithms [20]. Reliability in operations management pertains to a system's capacity to function without any glitches over an extended period, while maintainability centers on the efficiency and simplicity of restoring it after a breakdown. Both play a crucial role in ensuring optimal efficiency, productivity, and customer satisfaction while also minimizing downtime and cutting costs [21]. For this study, Markov processes, Chapman-Kolmogorov equations, genetic algorithm techniques, and normalization methods are used to make a ball mill unit in a series-parallel system work better. This optimization leads to improved maintenance planning and overall effectiveness [23].

This paper aims to improve our understanding of rock gold processing plant performance and aid in optimizing efficiency and productivity in the mining sector. Investigating optimization strategies to enhance the processing plant's operational efficiency in the future is advisable. This should be done while considering various constraints, such as budgetary limitations, resource availability, and compliance with environmental requirements. Optimization methods can be used to improve overall efficiency and determine the most effective operating strategies and maintenance plans. Despite extensive research, the topic of this paper, the rock gold plant, still faces significant research gaps. This study addresses these gaps by scrutinizing crucial aspects that the existing literature has either undervalued or neglected. This research seeks to greatly advance our understanding of the rock gold plant by carefully examining and analyzing it, adding to the corpus of knowledge on this subject. To address the existing knowledge gap, it is necessary to investigate the fusion of artificial intelligence (AI) and machine learning, as well as the utilization of Internet of Things (IoT) devices for instantaneous monitoring. Additionally, interdisciplinary methodologies such as reliability engineering and data analytics can be employed to enable predictive maintenance, thereby enhancing efficiency, dependability, and sustainability.

II. MATERIALS AND METHODS

A. System description

A description of the rock gold processing plant is given below, and a schematic diagram of the plant is shown in Figures 1 and 2.

1) Jaw-crusher: By applying compression to the material, the jaw crusher breaks it into smaller pieces that the gold processing plant can process. The entire system is dependent on the performance of a single jaw crusher unit. The entire system will suffer if this unit ceases to function.

2) Belt conveyor: The belt conveyor is an essential component in the rock gold processing plant, ensuring the smooth and efficient transfer of materials throughout the various stages of the processing operation. Its dependable performance and impressive capacity make it an essential element in the manufacturing process. The performance of a single belt conveyor unit is crucial for the entire system. The entire system will suffer if this unit malfunctions.

3) Ball mill: The ball mill in a rock gold processing plant operates through continuous rotation, crushing, and grinding of the ore to attain the desired particle size for effective gold extraction. There is a single unit of ball mill; if this unit fails, then the whole system fails.

TABLE I
SUMMARY OF LITERATURE STUDIES COMPARED TO PREVIOUSLY PUBLISHED WORK

References	Objective	Methodology	Data	Software
Tyagi et al. [1]	Mathematical model for leaf spring plant	Markov approach, C programming	Leaf spring manufacturing	MATLAB
Wang et al. [6]	Reliability and availability analysis of redundant BCHP	Markov approach with state-space method	BCHP system	MATLAB
Gupta et al. [7]	Performance modeling of power generation	Markov technique, probabilistic approach	Thermal plant	MATLAB
Abdalla et al. [9]	Assessment of hybrid power generation system	Metaheuristic Scanning Genetic Algorithm (MSGA)	Wind-solar plant	IEEE-RTS-79
Chaudhary and Bansal [13]	Reliability investigation of the spirulina production plant	Gumbel-Hougaard copula	Spirulina plant	MATLAB-R2023a
Ozdemir et al. [15]	Modeling and simulation of a gold concentrator plant	Dissolution loop method	Gold plant	-
Fedotov et al. [14]	Integrated technology for processing gold-bearing ore	Gravity recoverable gold test	Gold plant	-
Bragin et al. [16]	Mineralogical examination of gold processing plant tailings	Krasnoyarsk Territory analysis	Gold plant	-
Chaudhary and Bansal [23]	System availability assessment and optimization of ball mill	Markov modeling and genetic algorithm	Gold plant	MATLAB-R2024a
This research	Development of a decision support system and performance optimization for a rock gold processing plant	Markov modeling, probabilistic approach, and genetic algorithm	Rock gold processing plant	MATLAB-R2024b

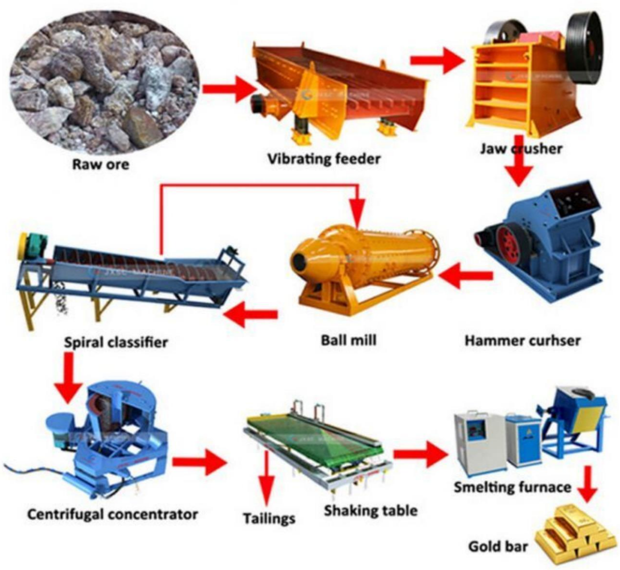

Fig. 1. Diagram of Rock Gold Processing Plant

4) Centrifugal concentrator: The centrifugal concentrator provides a highly efficient and cost-effective solution for extracting gold from ore, capitalizing on the varying densities of gold and other substances. The centrifugal concentrator seamlessly transfers the load to the second unit, allowing it to function as a replacement if one unit fails.

5) Shaking table: The shaking table utilizes the disparities in density among minerals to separate them effectively. Under the influence of gravity, heavier particles settle on the deck, while lighter particles wash away. This method is highly efficient in extracting fine-grained gold from ore. The shaking table seamlessly transfers the load to the second unit, allowing it to function as a replacement if one unit fails.

6) Gold furnace machine: A gold plant's gold furnace machine is an essential equipment for extracting and purifying gold from raw materials. It works by using the high-temperature melting concept to separate and collect the precious metal.

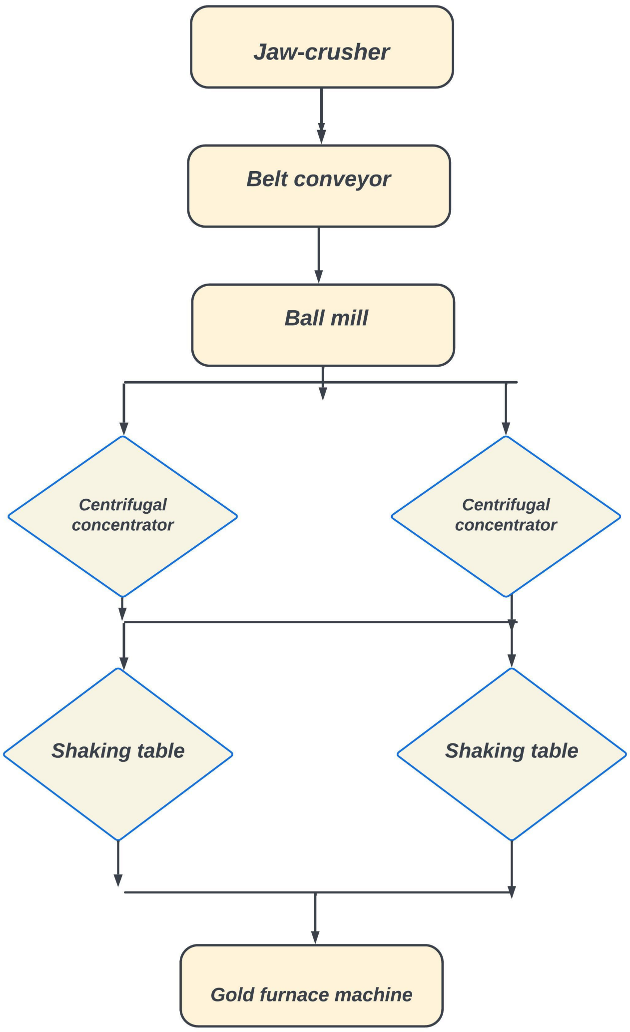

Fig. 2. Flow Diagram of Rock Gold Processing Plant

B. Assumptions

- The rates of failure and repair remain consistent over time and are statistically unrelated.
- A repaired component can perform just as well as a completely new one for a specified period.
- Repair facilities are well-equipped and efficient, ensuring minimal waiting time to start the repairs.
- Standby components have a similar nature to active components.
- The service provided includes both repair and replacement.
- The unit might operate at a reduced capacity.
- Simultaneous failures are not observed.

C. Notations

$w_1, w_2, w_3, w_4, w_5, w_6$: Failure rates of jaw crusher, belt conveyor, ball mill, centrifugal concentrator, shaking table, and gold furnace machine.
$m_1, m_2, m_3, m_4, m_5, m_6$ Repair rates of jaw crusher, belt conveyor, ball mill, centrifugal concentrator, shaking table, and gold furnace machine.
$A_1, B_1, C_1, D_1, E_1, F_1$: Indicates the system's full working capacity.
D_2, E_2: Indicates the standby unit of the ball mill and centrifugal concentrator.
$A_1^{'}, B_1^{'}, C_1^{'}, D_2^{'}, E_2^{'}, F_1^{'}$: Indicates the subsystems are currently in a failed state.
$P_{k1}(t), P_{k2}(t), P_{k3}(t)$: Indicates probabilities for the reduced state.
$P_{k0}(t)$: Probabilities that at a time 't' the subsystems are working without a standby unit.
$P_{k4}(t) - P_{k23}(t)$Probabilities for the failed state.
d/dt: Represents the derivative at time t.

D. Mathematical modeling and formulation

Figure 3 shows a transition diagram that helped us make differential equations based on the Markov birth-death process. We used a probabilistic approach for each part of the rock gold plant. During the birthing process, a discrete alteration in the probability function transpires as a result of component failures. On the other hand, when something is dying, repairs to parts cause a singular regression in the probability function. We solve the differential equations recursively and then simplify them to steady-state conditions, which are typically crucial in process industries. The equations are as follows:

$$P_{k0}^{'}(t) + \sum_{i=1}^{6} w_i P_{k0}(t) = \sum_{k=4}^{5} m_k P_{k-3}(t) + \sum_{k=1}^{3} m_k P_{k+3} + m_6(t) P_{k7} \tag{1}$$

$$P_{k1}^{'}(t) + \sum_{i=1}^{6} w_i P_{k1}(t) + m_4 P_{k1}(t) = \sum_{k=1}^{3} m_k P_{k+9}(t) + m_4 P_{k8}(t) + m_6 P_{k13}(t) + m_5(t) P_{k3}(t) + w_4(t) P_{k0}(t) \tag{2}$$

$$P_{k2}^{'}(t) + \sum_{i=1}^{6} w_i P_{k2}(t) + m_5 P_{k2}(t) = \sum_{k=1}^{3} m_k P_{k+13}(t) + m_4 P_{k3}(t) + m_6 P_{k17}(t) + m_5(t) P_{k9}(t) + w_5(t) P_{k0}(t) \tag{3}$$

$$P_{k3}^{'}(t)+\sum_{i=1}^{6}w_iP_{k2}(t)+\sum_{i=4}^{5}m_iP_{k3}(t)=\sum_{k=4}^{5}m_kP_{k+14}(t)+\sum_{k=1}^{2}m_kP_{k+19}(t)+m_3P_{k22}(t)+m_6P_{k23}(t)+w_4(t)P_{k2}(t)+w_5(t)P_{k1}(t) \quad (4)$$

$$P_{ki}'(t)+m_jP_{ki}(t)=w_jP_{k0}(t), i=4,5,6,7, \; andj=1,2,3,6 \quad (5)$$

$$P_{ki}'(t)+m_jP_{ki}(t)=w_jP_{k1}(t), i=8,10,11,12,13, \; andj=4,1,2,3,6. \quad (6)$$

$$P_{ki}'(t)+m_jP_{ki}(t)=w_jP_{2k}(t), i=9,14,15,16,17, \; andj=5,1,2,3,6. \quad (7)$$

$$P_{ki}'(t)+m_jP_{ki}(t)=w_jP_{k3}(t), i=18,19,20,21,22,23, \; andj=4,5,1,2,3,6. \quad (8)$$

Now, solve the above equations using the normalizing method with initial conditions:
$P_{ki}(t)=1$, at t= 0, i=0
$P_{ki}(t)=0$, at t= 0, $i\neq 0$
The rock gold plant was analyzed by setting d/dt =0 and, $t\to\infty$ in equations 1 to 8.
The sum of all probabilities is 1
$\sum_{i=0}^{23}P_{ki}=1$

$$P_{k0}=[(1+(Q_7-Q_8K_1)(1+Q_1+Q_2+Q_3+Q_4+Q_6)+K_1(1+Q_1+Q_2+Q_3+Q_5+Q_6)+Q_9(1+Q_1+Q_2+Q_3+Q_4+Q_5+Q_6)+(Q_1+Q_2+Q_3+Q_6)]^{-1} \quad (9)$$

Where, $Q_1=w_1/m_1, Q_2=w_2/m_2, Q_3=w_3/m_3, Q_4=w_4/m_4, Q_5=w_5/m_5, Q_6=w_6/m_6, N_7=(w_4+w_5)/m_4, N_8=m_5/m_4, N_9=(1/m_4)(w_4+m_5)K_1-w_5/(m_4+m_5), K_1=(m_4+m_5+w_4+w_5)m_5/(w_4+m_5)(m_4+m_5)+(m_5w_5-w_4m_4)$ So, the study states availability is

$$A_r=P_{k0}+P_{k1}+P_{k2}+P_{k3} \quad (10)$$

$$A_r=[1+Q_9+K_1+(Q_7-Q_8)K_1]P_0 \quad (11)$$

E. Development of decision support system (DSS) of rock gold processing plant using genetic algorithm

Decision-making entails recognizing and choosing the optimal choice by the values, preferences, and objectives of the decision-maker. Decision-making requires evaluating various alternatives to determine which is most likely to achieve the intended results, acknowledging that we can only reduce uncertainty, not eliminate it, due to the rarity of comprehensive knowledge. Consequently, decision-making intrinsically entails a degree of risk. Decision theory improves this process by using logic and numbers to look at things that affect decisions, like possible outcomes, actions that can be taken, and the effects of those actions. The major objective is to assist decision-makers in selecting optimal strategies through the assessment of diverse scenarios. This methodology is very effective in tackling issues such as establishing inspection frequency, planning overhaul intervals, coordinating maintenance teams, or enhancing workshop operations, all of which significantly influence productivity. Genetic algorithms (GAs) use ideas from natural selection and genetics to make search and optimization tasks more efficient. This makes them especially adept at solving tough engineering problems. These algorithms are especially effective at determining optimal solutions by simulating evolutionary processes. We utilize genetic algorithms to improve the operational efficiency of a gold extraction facility. MATLAB, a robust technical computing and visualization package, facilitates genetic algorithms with its comprehensive collection of integrated computational, graphical, and animation features.

Genetic Algorithm (GA)

Input: Population size P_s, Crossover probability P_c, Mutation probability P_m, Maximum generations gen
Output: Best chromosome and its fitness value
Initialize a random population of size P_s
Define the fitness function $f(x)$
for each generation g from 1 to gen **do**
    Evaluate the fitness of each individual in the population
    Select individuals based on their fitness (e.g., roulette wheel or tournament selection)
    Apply crossover with probability P_c to generate offspring
    Apply mutation with probability P_m to introduce diversity
    Create the new population by replacing less fit individuals
end for
Select and return the best individual and its fitness value

MATLAB improves the efficiency of addressing optimization problems by reducing difficult computations, visualization, and programming through mathematical notation. Figure 4 displays the flowchart of the genetic algorithm employed in this application.

III. RESULT AND DISCUSSION

A. Subsystem performance of rock gold processing plant

The failure and repair rates of each system component have a major impact on the availability or performance of the subsystem of the gold plant. For ease of use in analyzing availability and performance, it is assumed that the failure rates of different subsystems follow an exponential distribution. The model serves as the basis for implementing plant maintenance policies. It is possible to compute the different availability levels for different combinations of repair and failure rates. The optimal combination of optimal maintenance techniques (w_i, m_i) may be chosen based on analysis.
Tables 2 through 7 evaluate the various levels of performance associated with the various combinations of failures and repair rates.

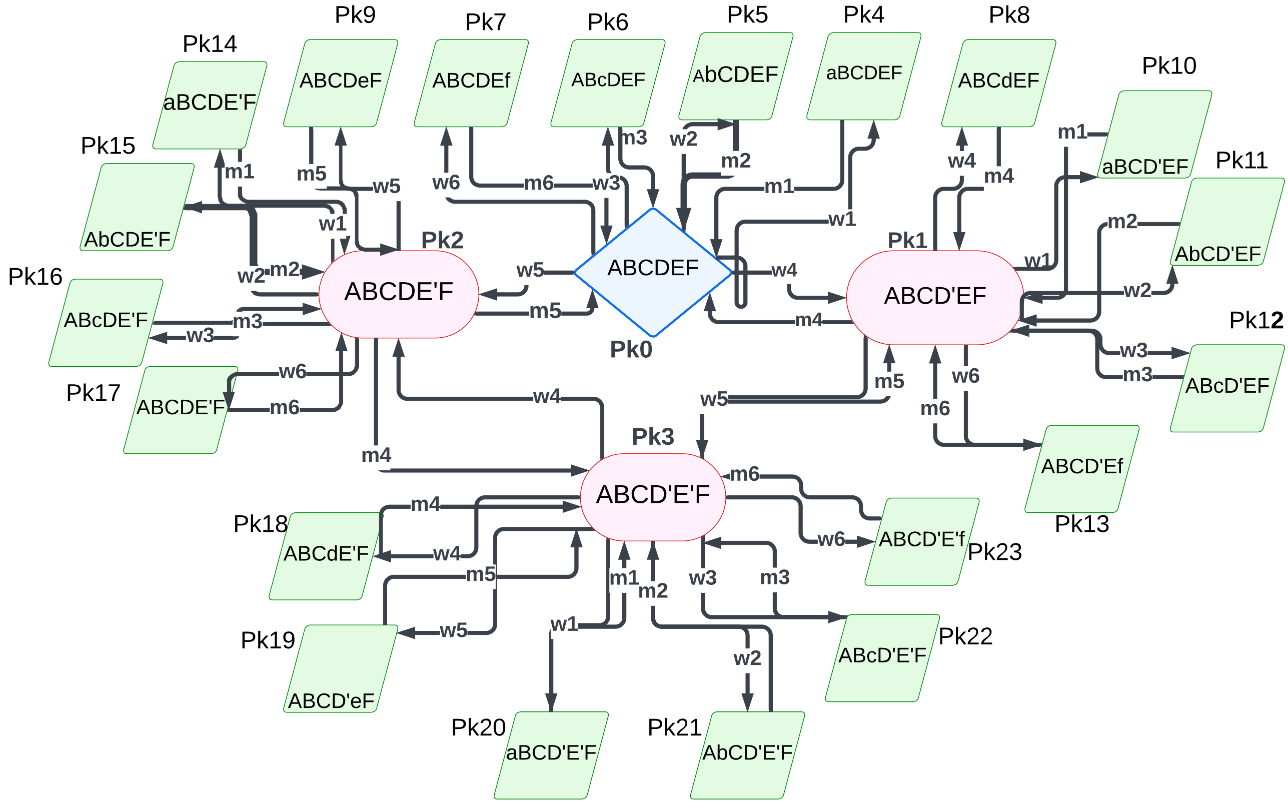

Fig. 3. Transition Diagram of Rock Gold Processing Plant

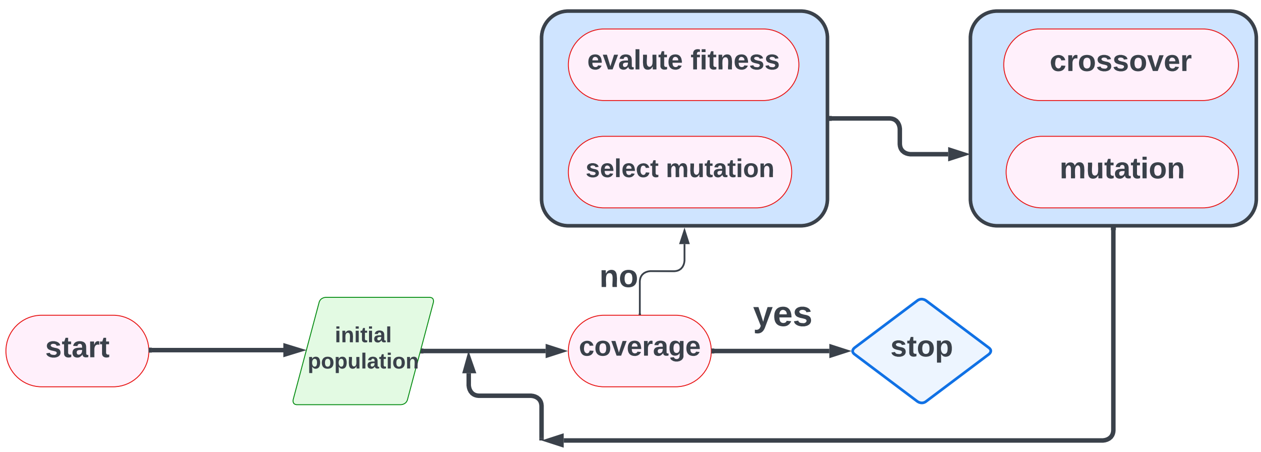

Fig. 4. Flow Diagram of Genetic Algorithm

Table 2 and Figure 5 indicate how the failure and maintenance rates of the jaw crusher unit are impacted by the availability of the rock gold plant. If the failure rate rises from .001 (once in 1000 hrs) to .01(once in 100 hrs) with an increment of.002, the availability of the system is reduced by 37.62%. In a comparable way, raising the repair rates from 0.02(once in 50 hours) to .22 with an increment of 0.04 eventually results in a 3.80% increase in the subsystem's availability. Constant parameters are:$w_2 = .002, w_3 = .004, w_4 = .004, w_5 = .005, w_6 = .002, m_2 = .04, m_3 = .07, m_4 = .09, m_5 = .08, m_6 = .06$.

TABLE II
MATRICES FOR 'JAW CRUSHER' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.001	0.003	0.005	0.007	0.009	0.01
0.02	0.7654	0.7874	0.7919	0.7939	0.7950	0.7957
0.06	0.7064	0.7654	0.7784	0.7841	0.7874	0.7894
0.10	0.6558	0.7447	0.7654	0.7747	0.7799	0.7833
0.14	0.6119	0.7250	0.7528	0.7654	0.7726	0.7772
0.18	0.5736	0.7064	0.7406	0.7564	0.7654	0.7713
0.22	0.5561	0.6974	0.7347	0.7519	0.7619	0.7683

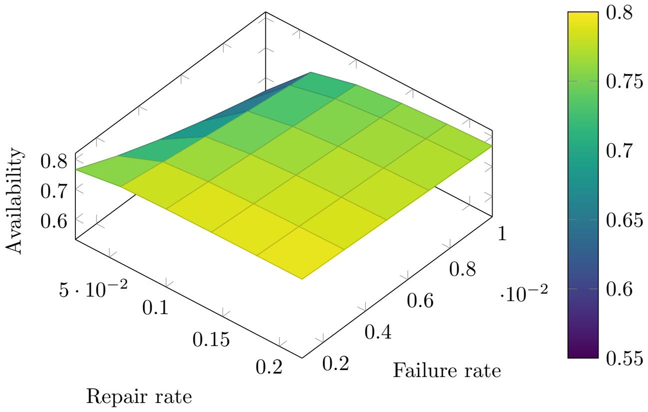

Fig. 5. Effect of Failure and Repair Rates of 'Jaw Crusher' Subsystem on Rock Gold Plant Performance

Table 3 and Figure 6 indicate how the failure and maintenance rates of the belt conveyor unit are impacted by the availability of the rock gold plant. If the failure rate rises from .002 (once in 500 hours) to .012 (once in 83 hours)with an increment of.002, the availability of the system is reduced by 20.90%. Comparably, raising the repair rates from 0.04(once in 25 hours) to .24 (once in 4 hours)with an increment of 0.04 eventually results in a 3.48% increase in the subsystem's availability. Constant parameters are: $w_1 = .001, w_3 = .004, w_4 = .004, w_5 = .005, w_6 = .002, m_1 = .02, m_3 = .07, m_4 = .09, m_5 = .08, m_6 = .06$.

Table 4 and Figure 7 indicate how the failure and maintenance rates of the ball mill unit have an impact on the availability of the rock gold plant. If the failure rate rises from .004(once in 250 hours) to 0.014 (once in 60 hours) with an increment of.002, the availability of the system is reduced by 11.94%. Comparably, raising the repair

TABLE III
MATRICES FOR 'BELT CONVEYOR' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.002	0.004	0.006	0.008	0.01	0.012
0.04	0.7654	0.7347	0.7064	0.6801	0.6558	0.6331
0.08	0.7818	0.7654	0.7497	0.7347	0.7202	0.7064
0.12	0.7874	0.7762	0.7654	0.7549	0.7447	0.7347
0.16	0.7902	0.7818	0.7735	0.7654	0.7575	0.7497
0.20	0.7919	0.7851	0.7784	0.7719	0.7654	0.7591
0.24	0.7930	0.7874	0.7818	0.7762	0.7708	0.7654

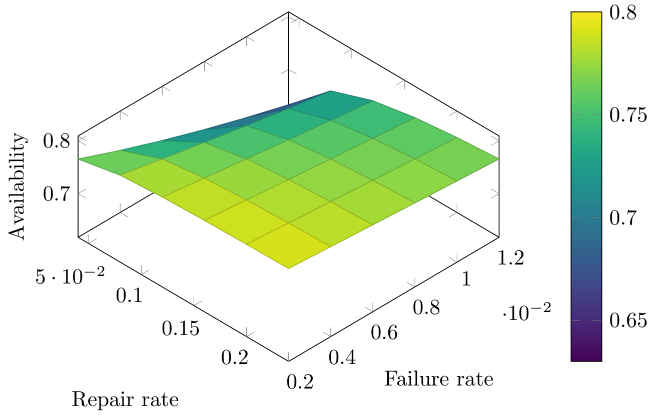

Fig. 6. Effect of Failure and Repair Rates of 'Belt Conveyor' Subsystem on Rock Gold Plant Performance

rates from 0.07(once in 14 hours) to .27(once in 4 hours) with an increment of 0.04 eventually results in a 3.53% increase in the subsystem's availability. Constant parameters are:$w_1 = .001, w_2 = .002, w_4 = .004, w_5 = .005, w_6 = .002, m_1 = .02, m_2 = .04, m_4 = .09, m_5 = .08, m_6 = .06$.

TABLE IV
MATRICES FOR 'BALL MILL' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.004	0.006	0.008	0.01	0.012	0.014
0.07	0.7654	0.7476	0.7305	0.7142	0.6986	0.6837
0.11	0.7789	0.7671	0.7556	0.7444	0.7335	0.7230
0.15	0.7854	0.7765	0.7679	0.7594	0.7511	0.7429
0.19	0.7892	0.7821	0.7752	0.7683	0.7616	0.7550
0.23	0.7917	0.7858	0.7800	0.7743	0.7686	0.7630
0.27	0.7935	0.7884	0.7834	0.7785	0.7736	0.7688

Table 5 and Figure 8 indicate how the failure and maintenance rates of the centrifugal concentrator unit have an impact on the availability of the rock gold plant. If the failure rate rises.004 (once in 250 hours) to 0.014 (once in 70 hours) with an increment of.002, the availability of the system is reduced by .3960%. Comparably, raising the repair rates from 0.09 (once in 11 hours) to 0.29(once in 4 hours)

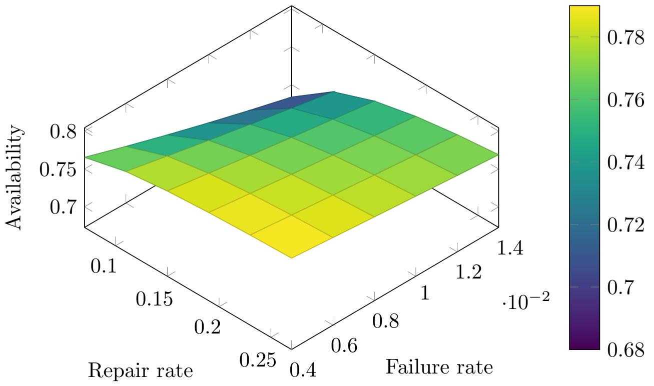

Fig. 7. Effect of Failure and Repair Rates of 'BALL MILL' Subsystem on Rock Gold Plant Performance

with an increment of 0.04 eventually results in a 0.1083% increase in the subsystem's availability. Constant parameters are: $w_1 = .001, w_2 = .002, w_3 = .004, w_5 = .005, w_6 = .002, m_1 = .02, m_2 = .04, m_3 = .07, m_5 = .08, m_6 = .06$.

TABLE V
MATRICES FOR 'CENTRIFUGAL CONCENTRATOR' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.004	0.006	0.008	0.01	0.012	0.014
0.09	0.7654	0.7648	0.7642	0.7636	0.7630	0.7624
0.13	0.7658	0.7654	0.7649	0.7645	0.7641	0.7637
0.17	0.7660	0.7657	0.7653	0.7650	0.7647	0.7644
0.21	0.7661	0.7658	0.7656	0.7653	0.7651	0.7648
0.25	0.7662	0.7660	0.7658	0.7655	0.7653	0.7651
0.29	0.7662	0.7661	0.7659	0.7657	0.7655	0.7653

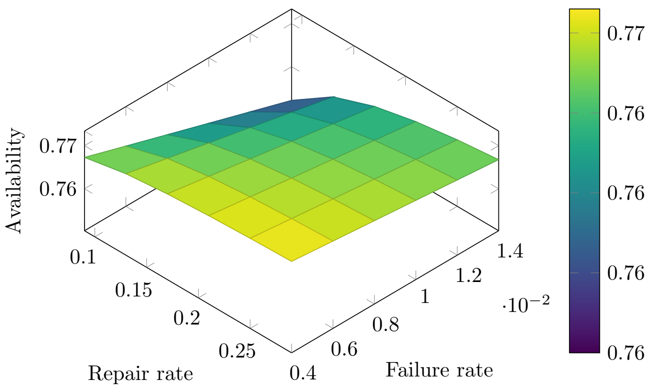

Fig. 8. Effect of Failure and Repair Rates of 'Centrifugal Concentrator' Subsystem on Rock Gold Plant Performance

Table 6 and Figure 9 indicate how the failure and maintenance rates of the shaking table unit have an impact on the availability of the rock gold plant. If the failure rate rises from .005 (once in 200 hours) to .015 (once in 70 hours) with an increment of.002, the availability of the system is reduced by .6151%. Comparably, raising the repair rates from 0.08(once in 12 hours) to .28(once in 3.5 hours) with an increment of 0.04 eventually results in a .2189% increase in the subsystem's availability. Constant parameters are: $w_1 = .001, w_2 = .002, w_3 = .004, w_4 = .004, w_6 = .002, m_1 = .02, m_2 = .04, m_3 = .07, m_4 = .09, m_6 = .06$

TABLE VI
MATRICES FOR 'SHAKING TABLE' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.005	0.007	0.009	0.011	0.013	0.015
0.08	0.7654	0.7645	0.7635	0.7626	0.7617	0.7607
0.12	0.7662	0.7656	0.7649	0.7643	0.7637	0.7631
0.16	0.7666	0.7661	0.7656	0.7652	0.7647	0.7642
0.20	0.7668	0.7664	0.7661	0.7657	0.7653	0.7649
0.24	0.7670	0.7667	0.7664	0.7660	0.7657	0.7654
0.28	0.7671	0.7668	0.7666	0.7663	0.7660	0.7657

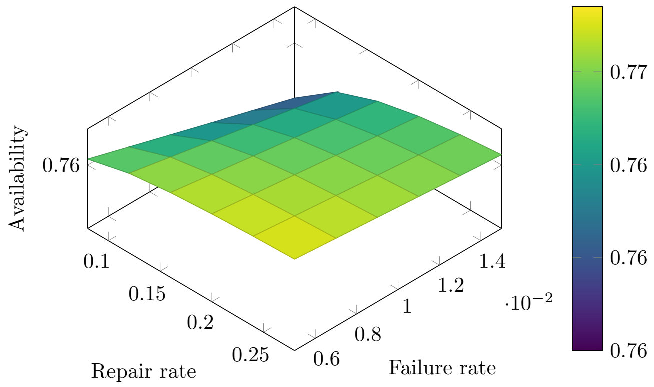

Fig. 9. Effect of Failure and Repair Rates of 'Shaking Table' Subsystem on Rock Gold Plant Performance

Table 7 and Figure 10 indicate how the failure and maintenance rates of the gold furnace machine have an impact on the availability of the rock gold plant. In the event that the failure rate rises.002(once in 500 hours) to .012(once in 80 hours) with an increment of.002, the availability of the system is reduced by 13.94%. Comparably, raising the repair rates from 0.06(once in 16 hours) to .26 (once in 4 hours)with an increment of 0.04 eventually results in a 2.14% increase in the subsystem's availability. Constant parameters are:$w_1 = .001, w_2 = .002, w_3 = .004, w_4 = .004, w_5 = .005, m_1 = .02, m_2 = .04, m_3 = .07, m_4 = .09, m_5 = .08$.

TABLE VII
MATRICES FOR 'GOLD FURNACE MACHINE' SUBSYSTEM OF ROCK GOLD PLANT

w_i	w_1	w_2	w_3	w_4	w_5	w_6
m_i	0.002	0.004	0.006	0.008	0.01	0.012
0.06	0.7654	0.7447	0.7250	0.7064	0.6886	0.6718
0.1	0.7740	0.7612	0.7487	0.7367	0.7250	0.71374
.14	0.7778	0.7685	0.7594	0.7505	0.7418	0.7333
.18	0.7799	0.7726	0.7654	0.7584	0.7514	0.7447
.22	0.7812	0.7752	0.7693	0.7635	0.7577	0.7521
.26	0.7822	0.7771	0.7720	0.7671	0.7621	0.7573

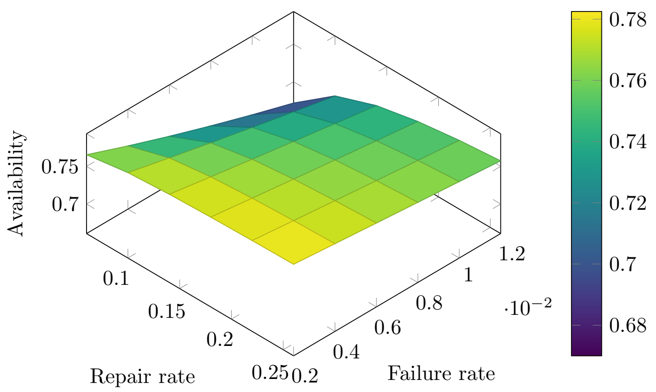

Fig. 10. Effect of Failure and Repair Rates of 'Gold Furnace Machine' Subsystem on Rock Gold Plant Performance

B. Performance optimized using genetic algorithm

The proposal is to have GAT coordinate the failure and repair parameters of each subsystem to ensure stable system performance, specifically high availability. The total number of parameters is twelve, consisting of six failure parameters and six repair parameters. The design procedure is outlined as follows:
To apply GAT to solve the given problem, it is necessary to encode the chromosomes as real structures. This instance uses mapped, concatenated, multi-parameter fixed-point coding. In contrast, the maximum and minimum values of system parameters are represented by the interval [min, max] for unsigned fixed-point integer coding parameters. The optimal values of system parameters align with the greatest value of the availability function. The intended availability level, or performance index, is used to optimize these parameters. Failure and repair rates are calculated simultaneously for the best unit availability value to test the suggested approach. Failure and repair rate parameters:
$w_1 \in (.001, .01)$,
$w_2 \in (.002, .012)$,
$w_3 \in (.004, .014)$,
$w_4 \in (.004, .014)$,
$w_5 \in (.005, .015)$,
$w_6 \in (.002, .012)$,
$m_1 \in (.02, .06)$,
$m_2 \in (.04, .24)$,
$m_3 \in (.07, .27)$,
$m_4 \in (.09, .29)$,
$m_5 \in (.08, .28)$,
$m_6 \in (.06, .26)$,
This application utilizes real-coded structures. The simulation accommodates a population size that varies between 10 and 90 individuals. Figure 11 illustrates the correlation between population expansion and the availability of rock gold plants. Setting the population size to 90 allows the unit to achieve its peak performance at 85.70%. Table 8 shows the optimal combination of failure and repair rates, and these are the best failure and repair rates: $w_1 = 0.0043$,
$w_2 = 0.0064$,
$w_3 = 0.0046$,
$w_4 = 0.0076$,
$w_5 = 0.0088$,
$w_6 = 0.005$,
$m_1 = 0.0567$,
$m_2 = 0.1355$,
$m_3 = 0.1061$,
$m_4 = 0.1494$,
$m_5 = 0.2459$,
$m_6 = 0.1836$.

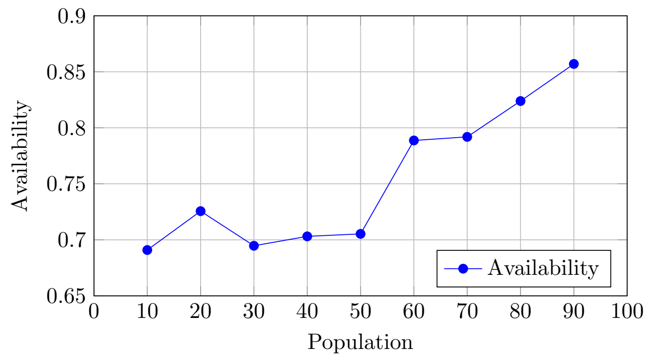

Fig. 11. Effect of number of population on fitness

The simulation's crossover probability ranged from 0.1 to 0.9. Figure 12 illustrates the correlation between the availability of the rock gold plant and the crossover random factors. With a crossover probability of 0.3, the plant reaches its highest level of performance. This is achieved by finding the best mix of failure and repair rates, resulting in an availability of 86.73%, as indicated in Table 9. $w_1 = 0.001$,
$w_2 = 0.005$,
$w_3 = 0.0124$,
$w_4 = 0.011$,
$w_5 = 0.0104$,
$w_6 = 0.0032$,
$m_1 = 0.0498$,
$m_2 = 0.1483$,
$m_3 = 0.093$,
$m_4 = 0.1287$,
$m_5 = 0.2207$,
$m_6 = 0.2345$.

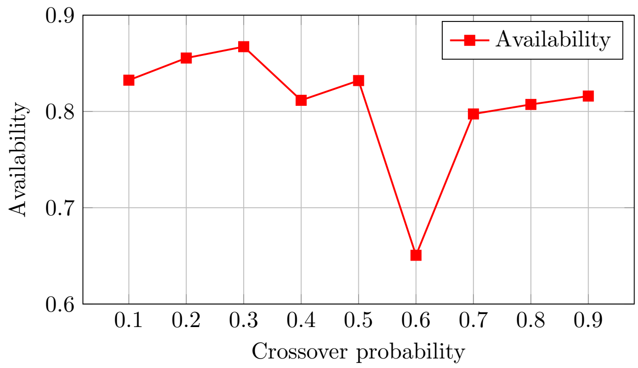

Fig. 12. Effect of crossover probability on fitness

TABLE VIII
EFFECT OF NUMBER OF POPULATION ON AVAILABILITY OF THE ROCK GOLD PLANT (CROSSOVER PROBABILITY= .90, MUTATION= .010, GENERATION SIZE =90

Population size	**Availability**	w_1	w_2	w_3	w_4	w_5	w_6	m_1	m_2	m_3	m_4	m_5	m_6
10	0.6909	0.0087	0.0041	0.0064	0.0078	0.0079	0.0095	0.0328	0.0615	0.2312	0.1404	0.1808	0.068
20	0.7256	0.0066	0.0059	0.0071	0.0073	0.0143	0.0067	0.02	0.1852	0.1499	0.0946	0.2075	0.1479
30	0.6947	0.0063	0.0082	0.0085	0.0045	0.0122	0.0094	0.0362	0.0503	0.2596	0.2655	0.2455	0.1497
40	0.7031	0.009	0.0105	0.0105	0.0091	0.0058	0.0056	0.0292	0.212	0.1969	0.2363	0.1113	0.2499
50	0.7053	0.0046	0.0081	0.012	0.0109	0.005	0.007	0.0594	0.0414	0.0782	0.1107	0.2007	0.0692
60	0.7887	0.0048	0.0056	0.011	0.0076	0.0082	0.0088	0.0433	0.0881	0.145	0.1309	0.1317	0.2295
70	0.7919	0.0048	0.0086	0.0093	0.0134	0.0083	0.0056	0.0499	0.2128	0.0744	0.2599	0.2415	0.1686
80	0.8239	0.0049	0.008	0.0074	0.0118	0.006	0.0065	0.0505	0.1652	0.0703	0.0934	0.1714	0.1043
90	0.857	0.0043	0.0064	0.0046	0.0076	0.0088	0.005	0.0567	0.1355	0.1061	0.1494	0.2459	0.1836

TABLE IX
EFFECT OF CROSSOVER PROBABILITY ON AVAILABILITY OF THE ROCK GOLD PLANT(POPULATION SIZE = 90, MUTATION= .010, GENERATION SIZE =90)

Crossover probability	Availability	w_1	w_2	w_3	w_4	w_5	w_6	m_1	m_2	m_3	m_4	m_5	m_6
0.1	0.8325	0.0023	0.0027	0.0119	0.0125	0.0057	0.0072	0.0219	0.1355	0.1962	0.2330	0.2095	0.1365
0.2	0.8555	0.0018	0.0099	0.0046	0.0118	0.0084	0.0067	0.0317	0.2252	0.2163	0.2820	0.1615	0.1492
0.3	0.8673	0.0010	0.0050	0.0124	0.0110	0.0104	0.0032	0.0498	0.1483	0.0937	0.1287	0.2207	0.2345
0.4	0.8116	0.0082	0.0025	0.0133	0.0088	0.0111	0.0104	0.0570	0.1456	0.2648	0.1050	0.1249	0.2370
0.5	0.8321	0.0036	0.0054	0.0116	0.0079	0.0128	0.0036	0.0501	0.2084	0.0949	0.1068	0.2791	0.1016
0.6	0.6506	0.0074	0.0106	0.0052	0.0095	0.0116	0.0097	0.0258	0.0759	0.2503	0.2822	0.1003	0.2192
0.7	0.7974	0.0050	0.0035	0.0053	0.0100	0.0116	0.0025	0.0339	0.0952	0.0858	0.2830	0.2436	0.1983
0.8	0.8073	0.0037	0.0051	0.0070	0.0046	0.0108	0.0096	0.0558	0.0713	0.2448	0.2765	0.2172	0.1840
0.9	0.816	0.0034	0.0073	0.0078	0.0132	0.0079	0.0055	0.0257	0.1968	0.1910	0.2274	0.1590	0.1409

1) Behavior of Subsystems in a Rock Gold Plant:

- The steady-state availability is substantially influenced by the jaw crusher and ball mill.
- The centrifugal concentrator and shaking table have negligible impact.
- The repair rate of the ”jaw crusher” subsystem has been enhanced, resulting in a 3.80% increase in the plant’s availability.
- Subsystems are given priority in maintenance decisions to boost performance.

TABLE X
BEHAVIOUR STUDY OF THE SUBSYSTEM

Subsystem	m_i	Perf.	prior.
Jaw crusher	.02-.22	.7654-.7957(3.80%)	I
Belt conveyor	.04-.24	.7654-.7930(3.48%)	III
Ball mill	.07-.27	.7654-.7935(3.53%)	II
Centrifugal Concentrator	.09-.29	.7654-.7662(.1083%)	VI
Shaking table	.08-.28	.7654-.7671(.2189%)	V
Gold furnace	.06-.26	.7654-.7822(2.14%)	IV

IV. CONCLUSION AND FUTURE SCOPE

A rock gold processing plant has established a decision support system. This will assist with establishing maintenance priorities for different sub-systems of the plant. This study demonstrates the proposed methodology to aid in such decision-making processes. A performance model has been created for evaluating the plant’s performance in the study. When it comes to maintenance, the “Jaw-Crusher“ sub-system takes top priority due to its critical importance. The “ball mill” should be given second priority as its failure and repair rates have a much greater impact on system performance compared to the “belt conveyor,” “gold furnace,” “shaking table,” and “centrifugal concentrator.” The paper introduces a mathematical model for enhancing the efficiency of a rock gold plant through the utilization of the genetic algorithm (GAT) and various parameters associated with genetic algorithms. The model allows for selecting the most effective combination of failure and repair parameters to achieve maximum availability, which is 86.73%. While the MBDP process achieved a maximum availability level of approximately 79.60%, Thus, using the genetic algorithm can significantly increase availability by 7.13%. The findings are discussed with plant executives, assisting maintenance managers in effectively planning and managing maintenance operations to optimize production, ensure high availability, and drive profitability. The model also helps maintenance engineers identify repair priorities for a specific system.

This project will integrate sophisticated machine learning techniques, including deep learning and predictive analytics, to increase maintenance planning and fault prediction accuracy, into the decision support system. Adding real-time data from IoT sensors to the genetic algorithm-based technique allows dynamic decision-making and adaptive maintenance scheduling. The model can also optimize efficiency and availability in other mineral processing facilities or complex system businesses. Future research may examine multi-objective optimization, which considers availability, energy efficiency, cost reduction, and environmental effects. Working with plant executives and engineers helps develop the model for practical deployment and better operational results.

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