Punam Rani, Sangeeta Malik, Arun Kumar
RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM) ANALYSIS
OF SOME PROCESS INDUSTRIES: A CRITICAL REVIEW OF LITERATURE

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Abstract

This paper reviews the literature on reliability, availability, and maintainability analysis of process industrial systems. In today's automated world, it is unfeasible to live exclusive of reliable systems, so every one of the working engineering system be anticipated to remain operational with maximum effectiveness for the longest period of time, or reliable operation. Throughout the years, the primary goal has been to concentrate on the system presentation in excess of an extended period of time; in essence, these are case studies on the system concert of industrial systems. While achieving 100% failure-free operation in production is not practicable, industrial systems that can be repaired can have their system failures minimized. In this paper, an effort has been made to compile the necessary literature and offer some helpful advice on how to broaden the field for more beneficial outcomes on system performance.

Keywords: Reliability, Availability, Process Industries, Redundancy

I. Introduction

The concepts of Reliability, Availability, and Maintainability (RAM) are becoming more and more important in today's industry. Utilizing RAM engineering techniques has become more crucial because to increase competition, stricter production timelines, financial restrictions, and the ongoing desire for lower-priced, higher-quality products. Reliability simulation has become the most popular and successful approach for handling contemporary real-world problems as industrial systems gets more complex. These problems are frequently hard or impossible to resolve with conventional analytical techniques.

RAM analysis is now the standard tool in many industries, thanks to the widespread use of this simulation-based technique. High capital expenditure is needed to halt manufacturing operations, particularly process plants like chemical, Bread, Urea fertilizer, sugar, thermal, polytube, washing unit, paper, and Rice, among others, because to the growing demand for automation across numerous industrial segments. For process facilities to survive, they must be highly productive and make the most money possible. The maximum level of equipment

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availability and dependability must be maintained in order to accomplish this goal. Unfortunately, this is not the case since, although it can be reduced via appropriate maintenance, inspection, operator training, incentive, and instilling a positive attitude in the workers, failure is unavoidable. Any system's performance has an impact on both the optimization tools and the quality of its design. Therefore, a system's performance can be improved by appropriate design, optimization at the design stage, and maintenance during its service life. One important factor in lowering manufacturing costs is careful maintenance planning. Improving the quality and expanding the availability of manufacturing systems are also very helpful in increasing productivity.

The word "reliability" comes from the very act of failure. The technology frequently malfunctions, making it unreliable for use. Both economically and in terms of safety, an unstable system has a very high cost. Catastrophic accidents could result from system breakdowns. As a result, industries are required to use the RAM technique to increase quality and safety. The numerous pieces of equipment used must be maintained as dependable and accessible as possible overall in order to do this. Because failures are inevitable, fault-free functioning is impossible. However, by using reliable parts, doing preventive maintenance on subsystems, and creating a happy work atmosphere, one might lessen their impact to some extent. Process industries employ a variety of reliability and maintainability performance events to evaluate the presentation of a system. Availability (i.e., intrinsic, operational, or achievable), turnaround time, and the routine maintenance cost index on stream factor and on-stream factor with slowness are the major measures used. In order to produce a variety of design possibilities, we usually consider system availability at every stage of the design process. If a system can perform its proposed function for the individual period of instance under all operational and environmental conditions, it is deemed reliable.

The availability of a system is its operational readiness, or its ability to carry out its intentional function immediately and for a particular epoch of time. System ease of use comes in different forms, such as inherent, achievable, and operational. Operational ease of use of the system in procedure industry includes wasted time in administration and operational logistics in addition to scheduled and unscheduled maintenance time. Achievable availability only includes scheduled and unscheduled maintenance time. In contrast, inherent availability simply accounts for unplanned maintenance time. Therefore, a system's dependability and maintainability are impacted by its availability. Maintainability refers to a system's capacity to apply prescribed maintenance procedures to keep it in a state where it is ready or presented to execute its future function under a range of operational and environmental conditions.

Process industries like chemical, bread, paper, Urea fertilizer, brewing, cement, thermal power plants, Polytube, and Rice plants also require their various subsystems to stay upstate for an extended amount of time in order to meet the requirements for high system availability and to make use of the maximum capacity of the plant. Nevertheless, unpredictable errors can occur in these systems or subsystems. Production may be decreased or may not occur at all, depending on the category and severity of the failure. It is undeniable that malfunctioning systems can be restored to functioning condition by replacing or repairing certain parts. However, in this instance, maintaining the system working at full capacity for the longest possible time depends heavily on the factory operating circumstances as well as the organization's repair practices. It would be necessary to have prior information of the system behavior, presented repair conveniences, etc. in order to design such a procedure as of the perspective of high structure availability. When assessing the presentation of subsystems and the level of interface among the ingredient subsystems, analysis and modeling of such systems may be helpful. An outline for structure aim base on accessibility and the best repair policy would also result from this. It is clear from the

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descriptions above that enhancing a system's dependability during design, improving its maintainability during operation, or doing both can all increase a system's availability. Unless compensatory reliability engineering measures are used, a system's dependability directly decreases as its complexity increases. Some organizations understand the importance of reliability and integrate it into all facets of their operations, such as the military, public utilities, and airlines. To avoid unscheduled shutdowns, process industries require a system that can ensure high availability and dependability. As a result, it is now evident how crucial high dependability is and how to achieve it by applying the many ideas described in the RAM approach. ODE-45 Method, Regenerative Point Graphical Technique (RPGT), Particle Swarm Optimization (PSO), Recursive Method, and Genetic Algorithm (GA) are only a few of the advanced performance optimization approaches that can be used further.

II. Basic Definitions

Reliability: Reliability will be probability of a gadget operating for a certain amount of time with no failure. More commonly, reliability is the ability of components, equipment's, components, solutions and items to do the required tasks of theirs for ideal stages of time with no disappointment in chosen environments and with a preferred confidence.

Availability: Accessibility will be the likelihood that a gadget is going to be in a position to work (i.e. not damaged or even going through repair) when called upon to do it. Much more particularly, it's the likelihood that the device is going to be ready to work within tolerance limits at a certain instant's and it is also identified as operational readiness.

Preventive Maintenance: In this type of maintenance, the subunits or subsystems are inspected before a failure and provided repair if required and maintenance be accepted out also when the structure has before now failed. The principle of preventive maintenance is to build the system working in its optimal capacity as soon as probable and that's why to add to availability of the structure. The time exhausted on every one this is negligible as repair of units may be online. This type of Maintenance is the act taken and pre planned so that an unfiled system or equipment remains to operational status including repairing a part or subunit that is answerable for the disappointment of the total system.

Failure: A deviation in the attributes from the prescribed problem is viewed as being a fault. A state of fault is widely known as "failure". An item is viewed as failed under among the following 3 conditions

- When it gets totally inoperable.
- When it's still operable, but is not in the position to do as needed e.g. a twelve volt battery offering three volt rather than twelve.
- When an unexpected critical deterioration makes the product unsafe for the further use of its.

Phases of Failure: Generally, a gadget might encounter any of three phases of failure throughout the total life cycle of it's of as well as operating.

Initial failure: Whenever we put a sizable collection of units to operation, it's very likely that you will find a lot of failures initially. The very early failures are called infant mortality or initial failures. These problems are because of manufacturing defects, for example poor assembly, vulnerable areas, defective styles etc.

Random failure (Chance failure): These failures happen while in the middle (useful life) of something as a result of unexpected strain accumulations outside of the layout power of the product. This kind of failures can't ever be predicted and so it's nearly impossible to eliminate them.

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Wear-out failure: With the way of time, the device (device) starts to decline. An easy change in the values of the variables identifying the functionality of the device happens when these variables go past the limit admissibility, the device breaks. This particular region is known as the wear-out region as well as such kinds of problems are known as wear out failures.

Failure Rate: It is characterized as the basic ratio of quantity of disappointments during a specific intermission to normal population throughout that stretch and is communicated in provisions of quantity of disappointments per unit instance.

III. RAM Methods For Process Industries: An Analysis of The Review of Literature

Historical Background: Over the past few years, the importance of reliability has grown among manufacturing companies, the government, and the general public. Agencies are attempting to obtain systems with improved reliability and cheaper maintenance costs as a result of current concerns about government spending. As buyers, our major priorities are choosing items with higher reliability, longer life spans, and lower maintenance costs. Each of us frequently uses the words "reliable" and "reliability" in daily life. Any stochastic system has the unique property that, in the event of failure of a relatively small number of its subsystems, the intact system fails. We encounter a number of issues related to work, social development, production, and administration every day. Reliability technology can help us solve problems if we have a thorough understanding of them and the right circumstances. The development of a system's infrastructure and the economics both revolve around reliability technologies. Technology today would not exist without reliability. It is especially crucial for a country like India to utilize its resources in the best possible way in order to maximize productivity through improved system reliability. It made a difference in reducing the elements that lead to system breakdowns. The particular word reliability = re + liability means recurring liability as of assorted breakdowns and failure of a structure. The person who designed the system or equipment, the manufacturer, quality control inspectors, actual user, and everyone else who is directly or indirectly connected to it must all share this responsibility. It can be difficult to identify and learn about every variable or circumstance that contributes to subsystem failures. Financial expert Pareto noted that a pair of elements typically account for the characteristic behavior of a dependent variable in several real-world situations, meaning that the majority of abnormalities are caused by a small number of independent causes. Due to the complexity of modern equipment, two additional factors maintainability and availability that are both strongly tied to reliability have come into sharper emphasis. When a piece of equipment is very reliable, breakdowns are less likely to occur and availability is higher. Additionally, accessibility will be high if a unit or framework can be fixed quickly (i.e., maintainability is high). This suggests that an item's low reliability can be compensated for by an increase in maintainability and availability.

For a very long time, reliability has been praised as a human quality. The reliability notion, however, has not been utilized for technical systems in more than 50 years. It first gained technological significance shortly after World War I. It was then applied to a comparison of the operational safety of single-engine, dual-engine, and four-engine aircraft. The frequency of accidents per hour of flight time was used to gauge reliability. A high level of reliability is expected of such equipment in the present scientific era where sophisticated systems are used for scientific, industrial, and defense applications. Due to the modern sophistication and growing complexity in the miniaturization of electronic and telemetric equipment necessary for defense and space research programming required for better degree of reliability, this demand has steadily developed since the end of the second world war. It would be risky to use equipment that might not work correctly when necessary when human lives and national security are at risk.

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Additionally, the modern military weapons are made up of tens of thousands of tiny components that are intricately braided together to form a weapon. The operation of the weapons could be negatively impacted by the failure of any of these. As a result, it is more crucial than ever that every component of complicated equipment be extremely trustworthy in order for the system as a whole to be reliable. High reliability is an important notion outside of the military.

Complex and sophisticated computers play a significant part in industrial and scientific activity. Even a single day of computer downtime results in inconvenience in addition to financial loss. Therefore, the more complicated the equipment, the less reliable it will be. Both discipline and measurement can be considered as aspects of reliability. Reliability as a subject focuses on the creation and deployment of methods for enhancing system effectiveness by lowering failure frequency and minimizing high maintenance costs. Reliability is focused with quantifying the level of equipment quality as a measurement. In reliability theory, a unit is a structure or a component of a system, and a unit is said to be operating when it performs within tolerances. A device's quality and reliability are inextricably linked. A unit's quality is determined by a number of factors that determine how suitable it is for a certain use. By structure reliability, we signify its capacity to perform well for the requisite period of time. Failure in the unit is the fractional or whole defeat of these attributes in an approach that partially or fully disrupts or stops its functioning.

Failures can roughly be divided into three categories: initial failures, random failures, and wear-out failures. Initial failures happen at the initial stages of a machinery process as a result of subpar manufacturing and quality control procedures. The cause of random failures is stress buildup that exceeds the unit's intended strength. These cannot be foreseen or stopped. Wear out failures originate from a slow change in the characteristics that determine a unit's quality. One definition of reliability is "a science that investigates the law of episode of failures in technical utensils and proposes corrective actions." The ability of a device or system to operate properly without a failure during a certain epoch of instant under a specific set of circumstances is thus described as the fundamental concept of reliability.

For about fifty years now, reliability engineering has existed as a separate field. The topic of repairable systems has yet to receive the attention it deserves in the literature on reliability. Examining the evolution of this engineering field aids in determining the causes of this shortcoming as well as the disturbances and challenges associated with analyzing repairable systems in terms of their availability, dependability, and maintainability. The evolution of quality control and reliability are closely related. Bell Telephone Laboratories in the United States established statistical approaches to address their quality control issues in the early 1920. This served as the foundation for extra advancements in the field of statistical quality control. Later, Bell Laboratories, the American Society for Mechanical Engineers, and the American Standard Association helped to popularize quality control methods.

The study's literature analysis prompted a thorough examination of the RAM factors. The literature study offers a modern viewpoint on the area and mostly covers the years 2000–2025. RAM has been the subject of numerous investigations in various process industries and other related domains. Through the use of RAM technology, a range of methods include been put out in the literature to improve system availability in process industries. RAM techniques have been used in process and related industries, as described by numerous scholars.

Borgonovo et al. [1] explored the Monte Carlo technique and proposed a plant maintenance strategy using their operating procedures. It was advised to use tools that help explain a range of plant executive and operations topics, including system repair, technological obsolescence, aging, and overhaul. Tang [2] anticipated a way for evaluating the dependability of a mechanical structure in the process industry based on the Boolean function. Based on the recommended work, the researcher created a formula for evaluating the system's dependability. The connection between various failure interactions using Boolean functions and graph theory.

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Using the method of finite element equations, Avontuur et al. [3] presented a novel methodology to assess the dependability of a system. Arulmozhi et al. [5] created the expression and algorithm to evaluate the dependability of a system amid K out of N components. The idea was quick and easy to implement, and it greatly enhances computing performance.

Elegbede et al. [6] put forth a revolutionary strategy that maximizes the system availability of repairable series-parallel systems by utilizing the Genetic Algorithms technology. Ebrahimi et al. [7 introduced an approach for assessing system dependability that mostly relied on failure data. A method was provided to review the consistency of a structure with high components of extremely high reliability because it is incredibly complex to obtain failure statistics for such systems.

A multi-period planning model and a preventative maintenance model were combined to develop a multipurpose plant optimization technique by Goel et al. [8]. It helps allocate the production and maintenance schedule by emphasizing preventative maintenance during equipment idle time and employing several production routes to reduce the brunt of equipment failure on creation.

Gupta et al. [9] discussed the accessibility of soap cakes making system. Xie et al. [10] advance to modeling the dependability of dependent structure by common cause failure (CCF) is presented. The method is founded on the idea of "conditional failure probability of component" as well as load-strength interference analysis at the system level. A discrete type system reliability model is created using the conditional component failure probability notion, which is based on the belief that load randomization is the direct cause of failure dependence. Finally, the model's ability to predict high multiplicity failure probability based on low multiplicity failure event data and estimate system dependability with CCF effect is demonstrated.

Gupta et al. [11] discussed the cement manufacturing plant. Samrout et al. [12] created a novel strategy for reducing the cost of preventative maintenance in systems with a series-parallel component layout by applying the Ant Colony optimization methodology.

Marseguerra et al. [15] developed a multi-objective optimization issue and employed the Genetic Algorithms technique to offer two more approaches to the problem's solution.

Gupta et al. [16] evaluated the reliability and accessibility of a industrialized facility using a K-out-of-N component system on behalf of a range of disappointment and repair rates. The plant's dependability was assessed using the Matrix Calculus Method and MATLAB software. It was found that using RAM approaches could enhance system output and quality. Krishnamoorthy and Viswanath [17] studied on the reliability of a k-out-of-n-system by way of restore by a Service Station Attending a Queue by way of Postponed Work.

A new framework for the best preventive maintenance of the pulping scheme used in the paper industry was created by Sachadeva et al. [20] using Petri Net. A probabilistic come up to utilizing the Markov procedure be used in the study by Kumar et al. [21] to analyze fertilizer plant availability and performance.

Khanduja et al. [23] optimized the act of a paper plant system by first developing mathematical models and then applying genetic algorithms. A mathematical formulation for the likely failure rates and repairs rates exponential distribution that were taken into consideration was created using a probabilistic approach. To find the steady state ease of use of the scheme, differential equations by the Markov Process are constructed and solved under normalize conditions. Hazra and Sinha [24] gave a fresh method for evaluating the event's sequence that could result in catastrophic disaster in a power phone. Probable collapse sequences happen to be realized offline for dissimilar likely loading scenarios by implementing an amended truth decoupled ton flow technique which thought the voltage as well as frequency dependence of loads as well as generator regulation attributes. Fuzzy evaluation as well as pattern recognition was utilized for internet recognition of cave in sequences for just about a few working problems as of the stored catalog.

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Kadyan [25] improved the stochastic analysis of a two unit parallel structure theme to degradation and assessment for viability of repair. Nourelfath et al. [26] analyzed multi formal method with planned manufacturing preparation as well as preventive upkeep. The authors likewise proposed a technique to assess the expense and also times of preventive maintenance, little fix as well as typical manufacturing capacity. A genetic algorithm was developed to cope with big size complications. In that job, the writers didn't evaluate the device under several failures.

Uemura et al. [27] considered accessibility styles of an incursion understanding structure, and also examined quantitative consequences of PM dependent on security road reliefs by utilizing Markov versions.

The performance of the steam generation scheme was assessed by Vora et al. [30]. A transition diagram was used to determine operational behavior, which was subsequently addressed using the Markov technique. Condition-based maintenance decisions have been proposed as a result of analyzing each availability. Gupta [31] discusses that the solitary unit system utilizing a base state.

Kim et al. [32] there are variety of research on standby machine of devices which can be repairable and which offers with evaluation of income and availability that entails the renovation that is preventive together with the above study, there may be a few interest can be given to the assessment of traits of reliability which can be income characteristic, availability and busy duration of machine which can be multi issue and regarding three out of four preparations having screw ups of 4 kinds. In the existing paper, got studied evaluation of income and availability of a machine that is redundant and repairable. This is three out of four installations with renovation of preventive which entails screw ups of 4 kinds through the use of the equations of chapman Kolmogorov method, improvement of express expression's for income characteristic and for availability of consistent country has been done.

Yusuf [33] there are number of studies on standby system of two units which are repairable and which deals with analysis of profit and availability that involves the maintenance which is preventive along with the above study, there is some attention will be given to the evaluation of characteristics of reliability which are profit function, availability and busy period of system which are multi component and involving 3 out of 4 arrangements having failures of four types. In the present paper, we have studied analysis of profit and availability of a system which is redundant and repairable.

Genetic algorithms for milk plant performance analysis and optimization were studied by Kajal and Tewari [34]. A probabilistic method was used to formulate the system in question formally, and the Markov procedure was second-hand to generate the differential equations. The optimal disappointment/ repair rates for the structure in question were calculated using Matlab.

Anand and Malik [35] cost-effectiveness of computer-assisted inspection was explored. There are two identical units in the computer organization. There are software and hardware components in both units. Both software and hardware can break at any time. It was assumed that hardware would need to be repaired and software would need to be replaced. In comparison to software replacement, hardware repair takes precedence.

Charzynska et al. [36] sensitivity of signaling pathways was investigated. Of this study, mathematical models are combined with experimental techniques to uncover the molecular machinery and relations in a scheme of interest. One of the goals of this study is to demonstrate how to use a range of mathematical approaches to model signaling network dynamics. Kim et al. [39] suggested the Recursive Decomposition Algorithm approach as a reliability evaluation technique for calculating the failure risk in networks with several initial connections, including sewage, electricity, water supply, and telecommunications. To reduce the overall cost of manufacturing, Doostprast et al. [40] urbanized a model for periodic PM of a scheme with optimal

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dependability based on simulated annealing. To prioritize repairs across subsystems and feed the sugar industry's feeding unit, a verdict support system was developed.

Choundary and Goel [41] discusses that the accessibility study of two dissimilar subunits framework with a standby consuming imperfect switch over expedient in banking Industry.

Kumar and Malik [43] discussed the reliability modelling of a computer framework with priority of hardware repair over spare. Single repairman is provided for repair, up gradation and preventive maintenance. Failure time distribution of hardware and software follows the negative exponential and PM, repair time are arbitrary.

Ranjan et al. [44] introduced a risk model base on gamma plus exponential failures. Foraging failures are linked to gamma failures, whereas accident failures are linked to exponential failures. Monte Carlo simulation and the Markov chain model were used for analysis. In contrast to an exponential distribution accidental failure curve, the model's curve will resemble a gamma model with aging failure predominating.

Damcese and Sodany [46] studied the system's Availability and reliability. In this paper, a stochastic version for the standby framework with reestablishment at every not unusual place cause, failure is created to recall the Markov process's dependability measures. Evaluations are completed for precise standards of machine stricture. Sensitivity evaluation is likewise executed to represent the impact of numerous limits at the dependability feature and imply time to disappointment of machine. Statistical instance is certain to demonstrate outcomes found.

Devi et al. [47] discusses that the Reliability and Behavioral Analysis of Yarn Industry of Malwa Region Using RPGT. Goyal et al. [48] discussed the behavioral analysis of two units system by preventive maintenance in cooperation units and dilapidation in individual Unit.

Ritikesh and Goel [49] this paper discusses about the behavior analysis of a system which has a single unit which go to degradation following having complete failure by the procedure of RPGT. At the initial stage the unit is doing work at complete capacity and this can have failure of two types, first one is the direct failure mode and second is by the partially failure. We have one repairman who checks and repairs these units on every failure we cannot retain the unit into its actual capacity after the complete failure.

Tseng et al. [50] this paper involved with sensitivity and dependableness analysis of a system that is governable having 'S' units of heat standby and 'M' units which are operative. Service times and failure times of standby units or in service units are alleged to go after the sharing which is exponential.

Krishnamoorthy et al. [51] studied on the Reliability of a k-out-of-n system by patch up by a single server extend service exterior customers with pre-emption. Zaitseva et al. [52] studied on the Importance analysis of k-out-of-n multi-state system base on direct incomplete logic derivatives.

Optimal Computing Budget Allocation (OCBA), Petri-net, and other state-of-the-art techniques, tools, and software were all covered by Kumar and Tewari [55] after they reviewed the literature on dependability, availability, and maintainability.

Poh et al. [56] have provided a choice support system to develop an all-inclusive analytic net model that would explain the interdependency between the components in the current situation.

Malik and Tewari et al. [57] performed recital modeling of the water flow structure, a subsystem of a thermal plant. Using a probabilistic evaluation that considered failure and repair rates based on recital modeling and individual component not a success and repair rates, maintenance priority were assign to a variety of mechanism. Devi et al. [58] calculate the MTSF and system availability using RPGT. The path examination of a three-unit standby stochastic organization was performed in this paper. In this system, two units are initially in operation alongside a third similar unit in cold standby mode, with the concept of two kinds of disappointments and repair facilities using ordinary or expert servers. Kumar et al. [59] discussed the sensitivity analysis of 3:4:: smart system plant is shaped with a lonely server which

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contains of 4 non-indistinguishable units within which elementary unit will add diminish state thanks to partial failure using RPGT technique. To evaluate the performance of complex systems with dynamic behavior, Penttinen et al. [60] proposed an Open Modeling approach that considers several RAM approaches.

Dahiya et al. [63] created a pan crystallization unit model with eight dissimilar subsystems using a fuzzy approach. In their 2019 study, Ahmadi et al. [64] used statistical approaches for performance modeling in combination with collapse and repair data to assess the reliability of the materials carrying system in an earth pressured balance tunnel uninteresting machine.

Kumar et al. [65] paper analyzed a sensitivity evaluation of a cold reserve device with precedence for defensive upkeep consist same devices with server disappointment the usage of RPGT. In this wok there are devices certainly considered individual among that is on-line at the same time as different is saved in cold standby mode? Single restore facility is to be had in 24*7. Repair and disappointment charges are continuous. State chart of basis delineating transition charges is drained. Analysis of work are executed which is probably useful to control in maintaining up one of a kind devices of device. Tables & figures are installation to have a take a observe and draw the conclusion.

Rajbala et al. [66] studied the structure modeling & psychoanalysis: a case revise EAEP manufacturing plant. Kumar et al. [67] studied the behavioral analysis of a washing unit in paper industry for scheme parameters using RPGT.

Chang et al. [68] suggested a technique to estimate the constraints on failure probability of a k-out-of-n system of components with potentially brittle behavior by breaking the system down into a set of subsystems and using linear programming (LP) and the universal generating function (UGF). Using numerical examples, the suggested method's accuracy and effectiveness are examined.

Rykov et al. [69] studied on the reliability function of a k-out-of-n system through specific restore time distribution. Agrawal et al. [72] discussed the profit analysis of a Water Treatment Reverse Osmosis Plant using the RPGT under specific conditions for scheme parameters. Numerical analysis is carried out for calculating the performance measures and their comparisons.

Kumari et al. [73] studied on the explanation of constrained problems by particle swarm optimization. Kumari et al. [74] discussed the behavior and profit analysis of a thresher plant in agriculture using RPGT under steady state.

Garg and Garg [75] studied the presentation analysis of the briquette machine in view of a neglected fault with PM used the Artificial Bee Colony algorithm to optimize the assessment of system profit.

Rohit and Poonia [77] study focuses on the mathematical modeling and sensitivity analysis of a steel mill made up of four subsystems using RPGT; all subsystem's exponential disappointment and specific repair rates are explored. Tables depict the structure behavior for repair rates of subsystems; the results demonstrate the practical trend and demonstrate that RPGT is a simple method for analyzing industrial facilities with similar topographies.

Kumar et al. [79] examined the RAM properties of various process industry systems. It gives a summary of how RAM practices have evolved historically and how they stand today within the intricate web of industries. To broaden the study, a thorough review of academic literature over the previous 20 years is carried out, including books, journals, and scholarly papers. The primary focus is on assessing RAM technique in various complex system and other process industries as well as diverse industrial contexts.

Bansal and Tyagi [80] analyzed the neural networks to optimize the casting process's performance characteristics. This article analyzes the availability, predictability, and state probability variation of the casting system using the Artificial Neural Network (ANN) technique.

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An attempt has been made to determine the system's most important component. The analysis's findings will assist practitioners in selecting efficient maintenance plans.

Arya and Verma [81] analyzed the integration of simulation approaches with environment modeling 2; this research investigates a novel approach to reliability and availability prediction. The suggested methodology allow for accurate estimate of failure probabilities and system downtime under various scenarios by capturing the dynamic interaction between embedded systems and their operating settings. The results show that, in contrast to conventional methods that ignore outside factors, environment-aware modeling greatly improves the accuracy of reliability and availability predictions.

RAM indicators for behavior in relation to assorted system parameters: The behavior of RAM indices in relation to assorted system factors examined by various authors is summarized in Table 1.

MTTF: mean time to system failure

IP: inversely proportional

DP: Directly proportional

Table 1: *RAM indicators for behavior in relation to assorted system parameters*

Sr. No.	Author's Name (References No.)	Index	Failure Rates (FR)	Repair Rates (RR)	Preventive Maintenance (PM)	Exchange Rate (ER)
1	Borgonovo et al. [1]	Availability and MTTF	IP	DP	-	-
2	Tang [2]	MTTF	IP	-	DP	-
3	Ke and Wang [4]	MTTF	IP	DP	-	-
4	Goel et al. [8]	Availability	IP	-	DP	-
5	Gupta et al. [9]	Availability	IP	-	-	-
6	Rizwan et al. [13]	Availability	IP	DP	-	-
7	Wang and Chiu [14]	Cost Benefit and Availability	-	-	-	DP
8	Nilsson and Bertling [18]	Profit and Availability	IP	-	-	-
9	EI-Said and EI-Hamid [19]	Availability	IP	-	DP	-
10	Haggag et al. [22]	Profit	IP	-	DP	-
11	Mathew et al. [28]	Profit	IP	-	DP	-
12	Mathew et al. [29]	Profit	IP	-	DP	-
13	AI-Alawi et al. [37]	Availability and MTTF	IP	DP	-	-
14	Padmavathi et al. [38]	Availability and MTTF	IP DP	DP IP	DP IP	- -
15	Padmavathi et al. [42]	Availability and Number of visits	IP DP	DP IP	- -	- -
16	Haggag et al. [45]	Profit and Availability	-	-	DP	-
17	Ram and Manglik [53]	Profit	IP	-	-	-
18	Adlakha et al. [54]	Profit	-	-	-	DP
19	Taj et al. [61]	Availability	IP	DP	DP	-
20	Kumar et al. [62]	Availability,	IP	-	-	-

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		MTTF and Profit				
21	Gupta et al. [70]	MTTF	IP	-	-	-
22	Gupta et al. [71]	MTTF	IP	-	-	-
23	Rajbala et al. [76]	Availability	IP	-	-	-
24	Dava and Lazakis [78]	Availability	IP	DP	-	-
25	Kumar et al. [79]	Availability and Maintainability	IP	-	DP	-
26	Arya and Verma [81]	Availability	IP	DP	-	-

IV. Research Gap

Following a careful examination of the literature, the following succinct observations are made on the submission of RAM approach in various complex process industry systems:

- In contrast to product-based businesses, the majority of research has concentrated on reliability in progression industries such as bread plants, urea fertilizer plants, rice plants, paper industries, dairy plants, and polytube plants. Few academics have looked at the relationship between availability and breakeven analysis, despite the fact that many have investigated ways to increase plant availability through efficient maintenance.

  It is noteworthy that the time required to arrive at the break-even point is directly shortened by increased plant availability. The majority of research has employed Markov modeling to assess industrial systems' performance using steady-state availability. Few, though, have attempted to solve these mathematical models in more practical industrial settings.

V. Conclusion

Through the literature review, we have concentrated on the diverse perspectives offered by a large number of reliability engineering researchers. Numerous aspects that affect a system's dependability have been analyzed. Studies on availability analysis of different process sectors have also been conducted. Following a comprehensive literature review, this piece will present an impression of the RAM methodology and discuss a variety of RAM-related issues, tools, and strategies used in dissimilar process industries to reduce overall failure costs, including maintenance and unplanned shutdown costs. The many models, software applications, tools, and processes can be used both in the design and operating phases. The two most common approaches in the literature are the dependability approach and the maintenance method. When reliability focuses on the many possibilities, system availability increases. On the other side, the maintenance method's primary focus is the minimum repair policy. Numerous results on RAM approaches were found in a review of the literature, along with several research gaps that require consideration and filling. The literature has a large number of publications on RAM (performance modeling, analysis, and optimization approaches) from several process industries, including paper, heat, fertilizer, pipe, and sugar. The creation and evaluation of mathematical models for theoretical performance is the only study that has been documented in the literature. Furthermore, an appropriate maintenance decision support system can be constructed using a range of RAM methodologies, depending on the behavior and performance characteristics of the assortment of system in the related process industries. Following a review of pertinent literature, the RAM approach can be used to prioritize equipment repairs when they happen during operation, identify production bottlenecks, detect failures during the design phase, compare and contrast various production design options, and optimize maintenance schedules.

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VI. Future Scope

As demonstrated in this study, researchers have made important charity to the pasture of dependability analysis through conventional modeling. It is now time to seek out some diversification and employ novel maintenance models that incorporate fuzzy and probabilistic methodologies. At various information levels, novel stochastic process is needed to satisfy the new necessities on behalf of repairable system. Instead of employing the traditional methods, new algorithms might be created to get the answers quickly. It would be much easier to arrive at near approximations to the actual results if the focus was on statistical inference application on preservation difficulties rather than merely searching for probability applications. The analysis in determining the resilience of maintenance models can also be supported by the statistical use of the goodness of fit test.

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