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A Critical Review of the Literature on Reliability, Availability, and Maintainability Approaches for Complex Systems in Different Process Industries

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Abstract

Industrial systems need to run smoothly and efficiently for as long as feasible to provide dependable performance in light of the rising demand for quality. Due to growing expenses, heightened competitiveness, and public expectations, it is imperative to assess these systems' performance while controlling the risk of possible malfunctions. Although it is unfeasible to achieve 100% failure-free operation in production, it is possible to minimize system failures in industrial systems that are repairable. This study examines the different aspects that affect system reliability and availability in process-based industries, with a focus on the Reliability, Availability, and Maintainability (RAM) approach. In addition to outlining procedures for performing RAM analysis, a review of RAM tools, techniques, and methodologies from the previous 20 years helps to clarify dependability and availability in complex process industry systems.

Keywords: *Reliability, Availability, Maintainability, Performance Evaluation*

Introduction

The very act of failure is the source of the word reliability. The system is unreliable for use due to frequent breakdowns. An unstable system comes at a very significant cost, both in terms of economy and safety. System malfunctions have the potential to cause catastrophic accidents. Therefore, using the RAM technique to improve quality and safety is mandated in industries. In order to achieve this, the many pieces of equipment employed must be kept as reliable and available as feasible overall. Fault-free operation is unachievable due to the unavoidable nature of failures. However, one can mitigate their impact to some degree by utilizing dependable components, performing preventive maintenance on subsystems, and fostering a positive work environment. Several reliability and maintainability performance metrics are used in process industries to analyze a system's performance. The primary metrics that are employed include availability (i.e., intrinsic, operational, or attainable), turnaround time, and routine maintenance cost index onstream factor and on-stream factor with slowness. Typically, we take system availability into account throughout the design phase in order to generate various design options.

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A system is considered reliable if it can carry out its intended function for the given amount of time, regardless of the operational and environmental conditions.

A system's operational preparedness, or its capacity to carry out its intended purpose instantly and for a predetermined amount of time, is referred to as its availability.

There are various types of system availability, including operational, attainable, and inherent availability. In process industries, operational availability of the system encompasses not only scheduled and unscheduled maintenance time, but also lost time in administration and operational logistics. Only the scheduled and unscheduled maintenance time is included in achievable availability. On the other hand, inherent availability only takes unscheduled maintenance time into account. As a result, a system's availability affects both its maintainability and dependability.

The ability of a system to maintain or recover its state, in which it is prepared or available to carry out its intended function under a variety of environmental and operational situations, through the use of maintenance following recommended protocols, is known as maintainability.

From the definitions above, it is evident that improving a system's availability can be achieved through improving its maintainability during operation, increasing its dependability during design, or doing both. The dependability of a system directly declines with increasing complexity unless compensatory reliability engineering techniques are implemented. Certain institutions, including the military, public utilities, and airlines, recognize the value of reliability and incorporate it into every aspect of their operations. Process industries need a system that can guarantee high availability and dependability in order to prevent unplanned shutdowns. Thus, it has become clear how important high dependability is, and how to attain it by utilizing the several concepts outlined in the RAM approach. Further application of a number of sophisticated performance optimization techniques, such as Particle Swarm Optimization, Fuzzy Methodology, and Genetic Algorithm, is possible.

RAM Approaches for Process Industries: A Critical Literature Review

Numerous studies on RAM have been conducted in a number of process sectors as well as other relevant fields. Numerous techniques have been proposed in the literature to increase system availability in process industries through the use of RAM technologies. Numerous academics have documented the implementation of RAM methods in process and associated industries.

Using their operating procedures, Borgonovo *et al.* (2000) presented a plant maintenance strategy and discussed the Monte Carlo technique. Tools that aid in describing a variety of aspects of plant management and operations, such as system repair, technological obsolescence, aging and renovation, were recommended. [1].

Based on the Boolean function, Tang J. (2001) suggested a way to assess a mechanical system's reliability in the process industry. The researcher developed a formula for assessing the system's reliability based on the suggested work. The link between different failure interactions utilizing graph theory and Boolean functions [2].

The algorithm and expression to assess the dependability of a system with K out of N components were developed by Arulmozhi *et al.* (2002). The suggestion helps to significantly improve computational performance and was quick and simple to implement [3].

Avontuur *et al.* (2002) described a novel approach to evaluating a system's reliability that makes use of the method of finite element equations [4].

A methodology for evaluating system dependability was presented by Ebrahimi *et al.* (2003) and was mostly dependent on failure data. Since it is very difficult to get the failure data of such systems, a method was given to evaluate the reliability of a system with high components of extreme high reliability [5].

Elegbede *et al.* (2003) proposed a novel approach that leverages the Genetic Algorithms technique to maximize the system availability of repairable series-parallel systems [6].

Goel, H.D. *et al.* (2004) created a multipurpose plant optimization technique that merged a multi-period planning model with a preventive maintenance model. By focusing on preventative maintenance during equipment idle time and using different production routes to lessen the effects of equipment failure on production, it aids in allocating the production and maintenance schedule [7].

Using the Ant Colony methodology of optimization, Samrout *et al.* (2005) developed a new way to lower the cost of preventative maintenance in systems with series-parallel component layout [8].

A multi-objective optimization problem was formulated by Marseguerra *et al.* (2006), who used the Genetic Algorithms technique to provide two other techniques for solving the problem [9].

The availability and dependability of a manufacturing facility with a K-out-of-N component system were assessed by Gupta *et al.* (2007) for various failure and repair rates. MATLAB software was utilized in conjunction with the Matrix Calculus Method to determine the plant's reliability. It was determined that employing RAM techniques could improve system quality and production [10].

Using Petri Net, Sachadeva A. *et al.* (2008) developed a novel framework for optimal preventive maintenance of the pulping system used in the paper industry [11].

The study conducted by Kumar S. *et al.* (2009) examined the availability analysis and performance evaluation of fertilizer plants using a probabilistic method using the Markov Process [12].

In 2010, Khanduja R. *et al.* created mathematical models and then used genetic algorithms to optimize a paper plant system's performance. Using a probabilistic method, a mathematical formulation was produced for the probable failure rates and repairs rates exponential distribution that were taken into consideration. Differential equations utilizing the Markov Process are created, and they are then solved under normalizing circumstances to determine the system's steady state availability [13].

Vora *et al.* (2011) evaluated the steam generation system's performance. Operational behavior was obtained using a transition diagram, and the Markov technique was then used to address it. Analyzing each's availability has led to the proposal of condition-based maintenance decisions [14].

An availability analysis of a lubrication oil system utilized in a combined cycle power plant was conducted by Thangamani *et al.* (2012). The concerned plant's system was modeled using a Generalized Stochastic Petri Net, which took into account partial failures of its subsystems and common causes of failures. These failures were then examined using a Monte Carlo simulation technique and a Petri Net [15].

Kajal and Tewari (2012) examined the use of genetic algorithms for performance analysis and optimization in milk plants. The concerned system was mathematically formulated using a probabilistic technique, and the differential equations were obtained using the Markov process. Matlab was utilized to determine the ideal failure and repair rates for the relevant system [16].

Recursive Decomposition Algorithm approach was proposed by Kim *et al.* (2013) as a reliability evaluation method for estimating the failure risk in networks with many starting connections, such as water supply, telecommunications, electrical, sewage, etc. [17].

Doostprast *et al.* (2014) created a model for simulated annealing-based periodic preventive maintenance of a system with optimal reliability in order to lower the overall cost of manufacturing. A decision support system was created to prioritize repairs across subsystems and feed the feeding unit of the sugar industry [18].

A risk model based on exponential and gamma failures was presented by Ranjan R *et al.* (2015). Gamma failures are associated with foraging failures, while exponential failures are associated with accident failures. For analysis, the Markov chain model and Monte Carlo simulation were employed. The model's curve will resemble a gamma model with ageing failure dominating, while an exponential distribution accidental failure curve will resemble the model [19].

After reviewing the literature on dependability, availability, and maintainability, Kumar and Tewari (2015) reported on a wide range of cutting-edge strategies, tools, software, and models, including Petri-net, Markov models, Artificial Bees' Colony algorithm, Optimal Computing Budget Allocation (OCBA), and Markov models [20].

Asjad *et al.* (2016) used an applied evolutionary algorithm to optimize the repair/maintenance cost for maximum availability after conducting a critical examination of the system's repair costs [21].

In order to create a thorough analytic network model that would explain the interdependency between the components in the given situation, Poh *et al.* (2017) have offered a decision support system [22].

The filling system of a carbonated soft drink glass bottle in the beverage producing industry has seven main subsystems arranged in series. Kumar and Tewari (2017) described the performance analysis and performance optimization of this system using the Particle Swarm Optimization (PSO) approach. For mathematical modeling, the Markov Approach (MA) was applied, which uses an exponential distribution of the expected failures and fixes [23].

Performance modeling of the water flow system, a subsystem of a coal-operated thermal power plant, was carried out by Malik and Tewari *et al.* (2018). The maintenance priorities were given to different components using a probabilistic evaluation that took into account the failure and repair rates, based on performance modeling and the rates of failure and repair of individual components [24].

Penttinen *et al.* (2018) suggested using an Open Modeling approach while taking into account different RAM approaches in order to assess the performance of complex systems with dynamic behavior. Using a fuzzy method, Dahiya *et al.* (2019) developed a pan crystallization unit model with eight distinct subsystems [25].

Ahmadi *et al.*'s [2019] study evaluated the materials hauling system's reliability in an earth pressured balance tunnel boring machine by utilizing statistical methodologies for performance modeling in conjunction with failure and repair data [26].

Conclusion

Following a thorough review of the literature, this section will explain the RAM methodology in its entirety, as well as the different RAM-related problems, tools, and techniques that are employed in various process industries to lower overall failure costs, which include maintenance costs and costs associated with unexpected shutdowns. It is possible to employ the different models, software programs, tools, and procedures both during the design and operation stages. The maintenance method and the reliability approach are the two predominant techniques found in the literature. System availability is increased when reliability concentrates on the different options. The minimum repair policy is the main focus of the maintenance method, on the other hand. Numerous findings about RAM methods were documented in a literature review, and a number of research gaps were noted that require consideration and resolution. The literature contains a variety of reports from diverse researchers on RAM (performance modeling, analysis, and optimization approaches) in a variety of process industries, including paper, heat, fertilizer, pipe, and sugar. The creation and evaluation of theoretical performance mathematical models is the only study that has been published in the literature. Furthermore, a suitable maintenance decision support system based on the performance characteristics/behavior of the various systems of the involved process industries can be constructed with the use of various RAM techniques. Once the relevant literature has been reviewed, the RAM approach can be used to identify production bottlenecks, detect failures during the design phase, compare and contrast different design options for production, optimize maintenance schedules, and prioritize equipment repairs when they occur during operation.

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