Advances in Dynamical Systems and Applications.
ISSN 0973-5321, Volume 16, Number 1, (2021) pp. 257-297

https://dx.doi.org/10.37622/ADSA/16.1.2021.257-297

A Review of the Reliability Analysis of the Complex Industrial Systems

Nabila Al Balushi
Department of Applied Mathematics and Science,
National University of Science and Technology, Muscat, Sultanate of Oman

Abstract

This paper is a review of the literature related to reliability analysis of complex industrial systems. Many industrial systems have been analysed over the last 3 decades under different operational conditions and assumptions. Mostly, the systems were analysed for estimating the reliability indices such as mean time to systems failure, availability analysis, failure frequency, mean down time, expected busy periods of the repairmen, and their respective cost-benefit analysis. The main objective all over these years was to focus on the system performance over a long period of time; it's basically case studies on system performance of industrial system. An attempt has been made in this paper to collect the sufficient literature and recommend some useful tips to diversify the discipline for more fruitful results on the system performance.

Keywords: Reliability, failure, repair, semi-Markov processes, regenerative processes, systems.

Notations

CC	Continuous casting
CBT	Computer-Based Test
D	Directly proportional
ER	Exchange rate
FR	Failure rate
IR I	nspection rate
I	Inversely proportional
M	Maintainability
MTTF	Mean time to system failure

PLC	Programmable logic controller
PM	Preventive maintenance
RBD	Reliability block design
RR	Repair rate

1. INTRODUCTION

The world is growing very fast and it is moving towards the direction of smart world in which technology is ruling everything and with the advance development of technology in the twenty first century has significantly increased cost and complexity of industrial systems. Thus it has become an essential to operate industrial systems with minimum down time in order to achieve optimized production, increase profit and to avoid the losses. Hence, the need for reliability modeling and analysis of complex industrial systems is inevitable.

Significant number of research has been carried out on the field of reliability modeling and and analysis of complex industrial systems under different operating conditions and assumptions.

To start with, need to see a review published by Taj and Rizwan [1] on reliability modeling and analysis of complex industrial system, where various reliability indices were presented with respect to different system parameters and type of distributions used for repair rate and failure by different authors have been discussed. Davis [2] discussed failure data and goodness of fit tests considering various failure distributions. Epstein and Sobel [3] worked in the field of life testing with the assumption of exponential distribution. Gaver [4] was the first to generalize repair time distribution and used supplementary variable technique to analyze the model. The concept of availability has been widely discussed in the literature of Sandler [5], Barlow and Proschan [6]. Srinivasan and Gopalan [7] concentrated on regenerative point techniques. Ramanarayanan and Usha [8] analysed n-units warm standby system using Erlang distribution. Usha and Ramanarayanan [9] further extended their previous work for the analysis of two n-unit cold standby systems using Erlang distribution. Kumar and Agarwal [10] presented a review of standby redundant systems. Afterwards, Yasmashiro [11] used supplementary variable technique to analyze a repairable system with n failure modes and k standby units. Gopalan and Naidu [12] analysed a one-server two-unit system subject to non-negligible inspection time for busy period. Rastogi *et.al.* [13] studied the effect of intermittent repair in a two unit redundant system with standby failure. Murari *et.al.* [14] carried out cost analysis in two-unit warm standby models with a regular repairman and patience time. Yearout *et.al.* [15] also presented a review of standby redundancy in reliability. Goel and Sharma [16] estimated reliability and availability of a 2-unit standby system with two failure modes and slow switch, using regenerative point techniques. Further, Goel and Shrivastava [17]-[19] focused on two-unit redundant system with provision for rest and correlated failures and repairs. Gupta and Bansal [20] calculated the profit of a two-unit cold priority standby system subject to degradation, whereas, the profit of a two unit-cold standby system with abnormal weather condition was calculated by Gupta and Goel [21]. Taneja *et.al.* [22] carried out profit analysis of a system with perfect repair at partial failure and priority for repair to complete failed unit. Tuteja and Taneja [23] applied semi-Markov processes and regenerative processes to determine various reliability measures for a two-server, two-unit, warm standby system. Gupta *et.al.* [24] handled a two-unit priority standby system subject to degradation and random shocks. Martin [25] discussed condition monitoring and fault diagnosis in machine tools, in his review paper. Gopalan and Bhanu [26] performed cost analysis of a two unit repairable system subject to on-line preventive maintenance and/or repair. Rajamanickam and Chandrasekar [27] discussed Marashall Olkin distribution for failure and repair rate, while analyzing two-unit systems with a dependent structure for failure and repair times. Li *et.al.* [28] worked on repairable system with three units and two repair facilities, and analysed the model using supplementary variables method. Tuteja *et.al.* [29]-[30] investigated a two server system with regular repairman who is not always available, and, estimated the profit of a two unit cold standby system with tiredness and two types of repairman. Tuteja *et.al.* [31] estimated the profit of a system with perfect repair at partial failure or complete failure. Rizwan *et.al.* [32] further carried out a comparative study between the profits of two models for a two unit system with rest period of repairman. Ke and Wang [33] presented reliability analysis of balking and reneging in a repairable system with warm standbys. Principles and applications of optimal reliability modeling have been discussed in detail by Kuo and Zuo [34]. Cost benefit analysis of a system with partial failure and alternative repair facility was presented by Rizwan and Mohiuddin [35]. Further, Rizwan and Mohiuddin [36] analysed stochastically a system with critical human error failure. Rizwan *et.al.* [37] carried out maintaince analysis of PLC. Rizwan *et.al.* [38] evaluated the reliability of a technological system with rest period of repairman. Rizwan *et.al.* [39] performed stochastic analysis of systems with accident and inspection.El-Said and El-Sherbeny [40] worked on two unit cold standby system with random change in unit and preventive maintenance. MTSF analysis of two unit system with partial failure mode was discussed by Rizwan *et.al.* [41]. Rizwan [42]-[43] discussed reliability modeling strategy of an industrial system and presented an application on reliability modeling. Rizwan *et.al.* [44] worked on maintaince analysis of a secondary coating line manufacturing machine. Rizwan *et.al.* [45]-[48] extensively analysed a hot standby PLC system, a single-unit PLC system, and a hot standby industrial system. Wang and Chiu [49] analysed the cost benefits of systems with warm standby units and imperfect coverage. Nilsson and Bertling [50] discussed cost and maintenance of wind power systems using condition monitoring systems. Parashar and Taneja [51] applied semi-Markov processes and regenerative processes while dealing with a hot standby system based on a master-slave and two repair facilities. Rizwan [52] further analysed a two unit system with two repairmen, for reliability. Wang *et.al.* [53] studied a repairable system with warm standbys and R unreliable service stations, and analysed the reliability and sensitivity of the model. Al Hemyari & Rizwan [54] presented a reliability analysis principles and modeling techniques to technological systems, and some important reliability indices are obtained for two unit cold standby system with a single repairman by using semi-Markov processes and regenerative point techniques. El-Said and El-Hamid [55] compared the reliability of two systems with preventive maintenance and different modes. Haggag [56],[57] calculated various costs for a two unit cold standby system with common cause failures and preventive maintenance using Kolmogorov forward equation, and for a repairable redundant 3-out-of-4 system involving preventive maintenance. Detailed analysis of a CC plant was reported by Mathew *et.al.* [58]-[60] wherein important performance indicators of the plant such as MTSF, availability etc were estimated. Mathew *et.al.* [61]-[65] continued working on the CC plant with scheduled maintenance policy, different installed capacities and full installed capacity; profit evaluation and comparative analysis between profits of two models of the CC plant were also presented. El-Said and El-Sherbeny [66] investigated the cost benefit analysis of a two unit cold standby system with two-stage repair of a failed unit and the techniques of regenerative point processes have been used to measure the effectiveness. Malik and Kumar [67] discussed two reliability models for a single-unit system where the repair facility is subject to failure during repair. Al Amri *et.al.* [68],[69] worked on reliability modeling and analysis of a refinery based centrifugal pump. A probabilistic analysis of recycle gas compressor was performed by AlCAmri *et.al.* [70]. Similarly, Al Maqbali *et.al.* [71] performed probabilistic analysis of an A.C. air compressor. Also, AlBalushi *et.al.* [72] conducted probabilistic analysis of sewage lifting centrifugal pump. Shakuntla *et.al.* [73] analysed the reliability of polytube industry using supplementary variable technique and MATLAB. Al Alawi *et.al.* [74] illustrated the application of reliability modeling and analysis for attaining zero failure performance for GIV Gulfstream Aircraft using semi-Markov process and regenerative point technique. Sharma *et.al.* [75],[76] presented reliability study of oil delivering system working at oil refinery plant wherein the system has the provision to switch over on another system in the event of failure. El-Sherbeny and Al-Hussaini [77] evaluated reliability of mixed standby components. Jiang *et.al.* [78] conducted reliability and maintenance modeling for dependent competing failure processes with shifting failure thresholds. Parashar *et.al.* [79] carried out reliability analysis of system consisting of three induced draft fans fitted in boilers used in thermal power plants using semi-Markov processes and regenerative point technique. Parashar and Bhardwaj [80] performed comparative profit analysis of two reliability models on a 2-unit PLC system. Kumar and Malik [81] developed a stochastic model a computer system of two identical units- one is initially operative and other is kept as spare in cold standby where in each unit h/w and s/w components work together and fail independently. The

reliability measures of a complex repairable series-parallel system involving four types of failures have been discussed by Suleiman et.al. [82]. Padmavathi *et.al.* [83]-[88] extensively analysed a desalination plant with online repair and emergency shutdowns, with priority for repair over maintenance, with minor/major failures and priority given to repair over maintenance, with major and minor failures and shutdown during winter season, and finally presented a comparative analysis of two models of the desalination plant. The methodology was extended for further analysis of desalination plant with mandatory shutdown during winter season and repair/maintenance on FCFS basis, and to compare different reliability models of the desalination plant. Ram and Singh [89] analysed cost benefits of a system under head-of-line repair approach and used Gumbel-Hougaard family copula. Ram *et.al.* [90] Stochastically analysed standby system with waiting repair strategy. Sharma and Kaur [91] performed availability analysis of an operating compressor working in a milk plant with three types of failure categories. Later Sharma and Kaur [92] presented comparative study between two reliability models for compressor standby systems with respect to MTSF between the models.
Yusuf and Hussiani [93],[94] evaluated reliability characteristics of 2-out-of-3 standby system under a perfect repair condition, followed by a comparison between three identical unit redundant systems with three types of failures using Kolmogorov's forward equation. Bhatti *et.al.* [95],[96] analysed identical and non-identical parallel system with failure followed by inspection policy using discrete distribution, then worked on dissimilar standby system with discrete failure. Gupta and Gupta [97] carried out stochastic analysis of a reliability model of one-unit system with post inspection, post repair, preventive maintenance and replacement. Detailed study of Markov processes for stochastic modelling can be found in Ibe [98] . Kadyan [99] studied a single unit system with preventive maintenance and evaluated reliability and profit. Kumar and Kapoor [100] discussed base transceiver system considering software based hardware failure and congestion of cells. Malhotra and Taneja [101]-[105] presented reliability and availability analysis of a single unit system with varying demand, stochastic analysis of a two-unit cold standby system wherein both units may become operative depending upon the demand, comparative analysis of two stochastic models subjected to inspection and scheduled maintenance, and a comparative study between a single unit system and a two-unit cold standby system with varying demand. Naithani *et.al.* [106]-[107] discussed cost benefit analysis of a 2-out-of-3 induced draft fans system with priority for operation to cold standby over working at reduced capacity, and probabilistic analysis of a 3-unit induced draft fan system with one warm standby with priority to repair of the unit in working state. Pathak *et.al.* [108] studied the case of one main unit and two supporting unit using regenerative processes. Pathak *et.al.* [109] extended the study to carry out profit analysis of a system having one main unit and two supporting units. Singh and Dubey [110] dealt with the reliability analysis of standby redundant system with critical human errors. Taneja and Malhotra [111] extended their previous work to perform cost-benefit analysis of a single unit system

with scheduled maintenance and variation in demand. Yang *et.al.* [112] have proposed a general statistical reliability model for repairable multi-component systems considering dependent competing risks, under a partially perfect repair assumption which considers that only the failed component, rather than the whole system, is replaced. Yusuf and Yusuf [113] discussed some reliability characteristics of a system under three types of failures with repair-replacement at failure, on the other hand, Yusuf and Bala [114] modeled a 2-out-of-4 warm standby system for MTSF. Yusuf and Koki [115] studied two-stage deteriorating linear consecutive 2-out-of-3 repairable system, whereas, Ali and Yusuf [116] worked on 2-out-of-4 repairable system with exchangeable unit to analyze availability and profit of model. Munjal and Singh [117] analysed a complex repairable system composed of two 2-out-of-3: G subsystems connected in parallel. Later, waste water treatment plant and anaerobic batch reactor were also analysed for the estimation of reliability indices of interest in order to assess the plant/reactor performance by Rizwan *et al* [118]-[120],[227]. Soni *et.al.* [121] handled m out of n warm standby system with repair facilities. Yusuf *et.al.* [122] performed stochastic modeling and analysis of a repairable 2-out-of-4 system. Singh *et.al.* [123] have focused on modeling and reliability analysis of internet data center with various maintenance policies. Pathak *et.al.* [124] calculated the mean time between failure and availability in a two-unit series repairable system with three states under consideration and single repair facility which repairs the units on first-come-first-serve basis. Later, Pathak *et.al.* [125] carried out comparative analysis on reliability parameter of a system under different types of distributions, weibull and Eriangian. Reliability and economic analysis for a power generating system was studied by Dalip and Taneja [126] comprising one gas and one steam turbine wherein the inspection for doing one of the three types of maintenance (Minor, Path or Major) is carried out randomly. A new directional network reliability model was proposed by Li *et.al.* [127] based on network and relevant failure and taking the component units as e nodes and the interaction relationships between the nodes as the side lines. Bhardwaj *et.al.* [128] analysed two identical unit cold standby system with geometric failure and repair time distribution. Also, Bhardwaj *et.al.* [129] analysed stochastically standby system with different failures. Aggarwal *et.al.* [130] proposed numerical method for reliability modeling and analysis of complex feeding system in a sugar plant comprising four repairable sub-systems arranged in series or parallel configurations.

Ahmad and Kumar [131] studied the profit of a two-unit centrifuge system and considered the halt state on occurrence of minor/major fault. El-Damcese and Shama [132] analysed 2-state repairable system with two types of failure for reliability and availability. Kumar *et.al.* [133] studied the behavior of a cold standby system with maximum repair time. Negi and Singh [134] worked on non-repairable complex system with weighed subsystems in series. Rizwan and Mathew [135] further extended their work for the performance analysis of port cranes. Babagana *et.al.* [136] introduced probabilistic models for redundant system reliability. Ram and Manglik [137] proposed reliability modeling of a an attendance monitoring system of an academic institute and evaluated the reliability measures of the system using Laplace transformation , supplementary variable technique, and Markov technique. Moreover, Bhardwaj and Singh [138] studied stochastically a cold-standby system with waiting for arrival and treatment of server. Kakkar *et.al.* [139] discussed two dissimilar parallel unit repairable system with failure during preventive maintenance. Kumar and Goel [140] analysed a two-unit cold standby system considering general distribution. Niwas and Kadyan [141] presented two reliability models of a single-unit system with the concept of preventive maintenance (PM) beyond warranty and degradation. Later, Niwas et.al. [142] evaluated MTSF and profit for a single unit system with inspection considering feasibility of repair beyond warranty. Sharma and Kaur [143] carried out cost benefit analysis of a compressor standby system with preference of service, repair and replacement is given to recently failed unit, on the other hand, Sharma and Sharma [144].[145] studied a standby system with provision of concomitant working, concurrent operation of standby units and maintaince facility. Moreover, Sharma and Kaur [146]-[149] evaluated reliability measures of two standby systems with concept of priority to failed Unit three units standby systems consisting of one standby and one generator, and finally evaluated the profit of three units compressor standby system. Singh *et.al.*[150] used copula to analyze the performance of complex system in series configuration under different failure and repair. Further, Taneja et.al. [151] presented a comparison between a single unit system with scheduled maintenance, and a two-unit cold standby system where both the units may become operative depending on the demand. Yusuf [152] then contributed to the reliability modeling of a parallel system with a supporting device and two types of preventive maintenance. Some challenges and opportunities in reliability engineering were discussed in detail by Zio [153]. Adlakha *et.al.* [154] carried out reliability and cost-benefit analysis of a two-unit cold standby system used for communication through satellite with assembling and activation time. Ahmed *et.al.* [154] worked on reliability modeling and profit analysis of repairable system working with one operative unit and three cold standby units. Ahmed *et.al.* [156] also dealt with the reliability analysis of a parallel unit system and two cold standby units. Lado *et.al.* [157] carried out analysis of a system with two subsystems consisting of two non-identical units and priority repair to the first failed unit. Al Rahbi *et.al.* [158]-[163] presented an extensive study for an aluminum manufacturing industry wherein, butt thimble removal station and rodding anode plant were analysed for important reliability indices under different operating conditions. Al Rahbi *et.al.* [164] further extended the study and performed comparative analysis between two models, a model of a Single component with Single repairman and a model with multiple repairmen of an Aluminum Industry.

Bhardwaj *et.al.* [165] estimated reliability indices of a redundant system with standby failure and arbitrary distribution for repair and replacement times. Fagge *et.al.* [166]

discussed the availability of a repairable system requiring two types of supporting device for operations. Goyal and Malhotra [167] conferred a systematic study of reliability on various models and they have studied the relation between system effectiveness and various system parameters. Also, they have discussed the distribution used by the various researchers. Keleş *et.al.* [168] proposed maintenance policies for systems subject to continuous-time Markovian deterioration, which may result in non-self-announcing failures. Mahmoud *et.al.* [169] worked on duplicated standby system. Mortazavi *et.al.* [170] studied 2-out-of-3 redundant system for MTTF considering common cause of failure and load share based on alpha factor and capacity flow models. Cost-benefit analysis of two non-identical units cold standby system subject to heavy rain with partial operation after repair, was presented by Singh *et.al.* [171]. Singh and Ayagi [172] then studied some reliability measures of system consisting of two subsystems in series, using copula. Detailed study of a cable plant was carried out by Taj *et.al.* [173]-[181] wherein, subsystem analysis, season based operating strategy, and comparative analysis between two models were presented and the study further extended the work to analyze wire drawing system of a cable plant with mandatory rest period. El-Damcese and Shama [182] dealt with a reliability analysis of k-out-of-n system in the presence of two types of failure where the two types of failure are independent and exponentially distributed. The reliability analysis of two non-identical unit's parallel system with two kinds of failures common cause failure and partial failures was studied by Abu-Youssef [183] preventive maintenance and waiting time to repair has also been incorporated. Kumar *et.al.* [184] developed a stochastic model for reliability assessment of non-identical unit's system using regenerative point technique. Later, Kumar *et.al.* [185] performed profit analysis of a system of non-identical units with warm standby unit working under different environment condition. Further, Kumar *et.al.* [186] extended the profit analysis of a warm standby non-identical units system with single server subject to preventive maintenance. Chaowei *et.al.* [187] presented a reliability calculation method for repairable system based on Monte Carlo simulation. Bhardwaj *et.al.* [188] focused on reliability analysis of diesel locomotive engine using Weibull distribution.

Niwas and Garg [189] proposed an approach for analyzing the reliability and profit of an industrial system based on the cost-free warranty repair policy and then Niwas and Kadyan [190] proposed an approach for analyzing reliability and profit of a single-unit system with repairman having multiple vacations. Extensive study presented by Sharma and Sharma [191]-[193] for power plant plant system. EL-Bassiouny [194] discussed the performance of power transformer in Egypt at different voltage levels in term of reliability, maintainability and availability. Kakkar et.al.[195] presented a reliability and availability analysis of a three-unit system under the provision of replacement of a unit using the Genetic algorithm to optimize the availability of the system. Kumar and Kumar [196] analysed the behavior of the system which of two components and work under cost free warranty policy. Again, both Kumar and Kumar [197] worked on analysis for various reliability parameters of rice manufacturing industry using Markov model. Lado and Singh [198] performed analysis of a system with two subsystems having two independent units in each using copula repair approach. Singh and Poonia [199] discussed the probabilistic assessment of two unit parallel system with correlated lifetime distribution under inspection using regenerative point technique. Sayed *et.al.* [200] presented a technique for reliability, availability and maintainability analysis of a grid connected PV system using exponential distribution using Reliability block diagram method.

Yusuf *et.al.* [201] carried out profit analysis of a serial-parallel system under prtial and complete failures. Yusuf *et.al.* [201] also dealt the reliability modelling and evaluation of a linear consecutive 2-out-of-4 system under online and offline preventive maintenance. Moreover, Yusuf [203] discussed the reliability characteristics of computer network system consisting of the devices load balancer, distributed database servers and a centralized server configured as series parallel system containing three subsystems. Gahlot et.al.[204] analysed the performance of a system having two subsystems in series configuration with switch over device and human failure. Gupta [205] analysed the reliability characteristics of generator in steam turbine power plant at component level using the fundamental concept of reliability theory and Markovian birth–death process to explore the system. Gupta *et.al.* [206] further extended the work and performed the behavioral analysis of cooling tower in steam turbine power plant using reliability, availability, maintainability and dependability approach. Bhatti *et.al.* [207] worked on reliability analysis of system processing active standby redundancy mode. Jagtap *et.al.* [208] evaluated the performance of a circulation system of water (WCS) used in a coal-fired power plant (CFPP) using a reliability block diagram (RBD), fault tree analysis (FTA), and Markov birth–death probabilistic approach. Kaur *et.al.* [209] presented a study on reliability modeling and analysis of a gravity die casting system which consists of seven main units. Raghav et.al. [210] studied a series of system that consists two subsystems of five and two units each and the probabilistic analysis of the system was obtained using copula repair approach. Sanusi and Yusuf [211] performed cost analysis of a hybrid series–parallel system consisting of two subsystems A and B, where Subsystem A has two units in active B consists of 2-out-of-4 units. Jain *et.al.* [212] obtained reliability measures of a stochastic model developed for a 1-out-of-2 system with single standby and delayed service. Recently, stochastic analysis of a repairable system of three units has been carried out by Kadyan *et.al.* [213] taking main unit in operation and two identical units in cold standby. Another stochastic analysis was performed by Singh and Gahlot [214] of a system consisting of two subsystems in a series configuration for different types of failure and two types of repair. Singh *et.al.* [215] presented the reliability measures of a complex system consisting of three computer labs connecting to a server in the parallel configuration under 2-out-of-3: G operation policy. Further, Singh et.al. [216] discussed performance analysis of a complex repairable system with two subsystems in series configuration with an imperfect switch. Singh *et.al.* [217] worked on probabilistic assessment of CBT network system which consists of four Subsystems in series Configuration using Copula linguistic approach. Also, Kumar *et.al.* [218] performed reliability analysis of a redundant system with FCFS repair policy subject to weather condition. Kumar et.al. [219] performed RAM analysis to improve the operational performance of soft water treatment and supply plant. Malhotra and Dureja [220] worked on reliability modeling of a two unit cold standby system for a pharmaceutical company with rest period and varying demand. Saini *et.al.* [221] investigated the performance measure of power generating system of sewage treatment plant to develop a methodology in increasing the performance of the system. Taj *et.al.* [222] extended pervious study and performed comparative analysis of three reliability models of a building cable manufacturing plant. Poonia and Sirohi [223] discussed the cost benefit analysis of k out of N G type warm standby series using Copula linguistics. Later, Poonia et.al. [224] extended the study and performed cost analysis under catastrophic failure using copula repair. Yusuf [225] developed reliability model of a parallel system with a supporting device and two types of preventive maintenance. Yusuf *et.al.* [226] recently worked on performance analysis of multi computer system consisting of three subsystems using Copula approach. Sharma and Sharma [228] presented study on steady state behaviour of a cold standby system consisting of turbine boiler and fans. Whereas, Sharma and Kaur [229] analysed the profit of four compressor unites standby system with priority given to recently failed unit.

In this review paper, the variation of various reliability indices with respect to different system parameters has been presented separately for each reference paper. Further, the different types of distributions for failure/repair rate used by various authors have been discussed. Finally, graphical study is carried out to illustrate the preference given to different types of distributions for failure/repair rate by various authors.

2. Behaviour of various reliability indices with respect to system parameters.

Table 1 summarises the behaviour reliability indices with respect to different system parameters studied by different authors.

Table 1. Behaviour reliability indices with respect to different system parameters

Reference Number	Reliability index	FR	RR	PM	RR	ER
Srinivasan & Gopalan [7]	MTTF					D
Usha & Ramanarayanan [8]	Availability					D
Gopalan & Naidu [12]	Busy period				I	
Rastogi *et.al.*[13]	Profit					D
Murari *et.al.* [14]	Profit	i	d			D

Goel & Sharma [16]	MTTF	I				
	Availability	I				
	Profit	I				
Goel & Shrivastava [17]	Profit	I				
Gupta & Bansal [20]	MTTF	I				D
Gupta & Goel [21]	MTTF	I	D			
	Profit	I	D			
Taneja et. al [22]	Profit	I	D			
Tuteja & Taneja [23]	MTSF	I	D			D
	Profit	I	D			D
Gupta et.al. [24]	Profit			D	D	
Gopalan & Bhanu [26]	Profit	I				
Tuteja et.al.[30]	Profit					D
Ke & Wang [33]	MTTF	I	D			
Rizwan *et.al. [37]*, [39],[47],[48]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
	Profit	I	D			
El-Said &El-Sherbany [40	MTTF	I	D	D		D
	Availability	I	D	D		D
Wang & Chiu [49]	Profit					D
Nilsson & Bertling [50]	MTTF	I				
	Availability	I				
	Profit	I				
Parshar & Taneja [51]	Profit	I	D	D		
Wang et.al. [53]	MTSF	I	D	D		D
Al Hemyari & Rizwan [54]	MTTF	I				

El-Said &El-Hamid [55]	MTTF	I		D		
	Availability	I		D		
Haggag [56]	MTTF	I		D		
	Profit	I		D		
Haggag [57]	Availability			D		
	Profit			D		
Mathew et. al [58]	MTTF	I	D			
	Availability	I	D			
Mathew et. al [59]	MTTF	I	D	D		
	Availability	I	D	D		
Mathew *et.al.* [60]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
	Profit	i	D			
Mathew *et.al.* [62]. [64]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
	Profit	i	D			
El-Said &El-Sherbany [66]	MTTF	I				
	Availability	I				
	Profit	I				
Al Alawi et.al. [74]	MTTF					
	Availability					
El-Sherbany & El Hussaini [77]	MTTF	I	D			D
	Availability	I	D			D

Parshar *et.al.* [79]	Profit				D	
Kumar et.al. [81]	Availability	I				
	Profit		D			
Padmavathi et. al [83]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
Padmavathi et. al [85]	MTTF	I	D	D		
	Availability	I	D	D		
	Busy period	D	I	I		
	Number of visits	D	I	I		
Padmavathi et. al [86]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
Padmavathi et. al [87]	MTTF	I	D	D		
	Availability	I	D	D		
	Busy period	D	I	I		
	Number of visits	D	I	I		
Ram & Singh [89]	Availability	I				
	Profit	I				
Ram et.al. [90]	MTTF	I				
	Availability	I				
Sharma & Kaur [91]	MTTF	I				D
	Profit	I				
Yusuf & Hussaini [93]	Availability		D			D
	Profit		D			D
Yusuf & Hussaini [94]	MTSF	I	D			
	Availability	I	D			

	Profit	I	D			
Bhatti et.al. [95],[96]	MTTF	I	D		D	
	Profit	I	D		D	
Gupta & Gupta [97]	MTTF			D	D	
	Availability			D	D	
	Busy period			I	I	
	Number of visits			I	I	
Kadyan [99]	Availability	I	D	D		
Kumar & Kapoor [100]	MTTF	I	D			
	Profit	I	D			
Malhotra & Taneja [102]	Profit					D
Malhotra & Taneja [104]	Availability	I				D
	Profit	I				D
Naithani et.al. [106]	Profit					D
Naithani et.al. [107]	MTTF					D
	Availability					d
Pathak et.al. [108]	MTTF	I	D			
	Availability	I	D			
	Profit	i	D			
Pathak et.al. [109]	MTTF	I				
	Availability	I				
	Profit	I				
Singh & Dubey [110]	MTTF	I				D
	Availability	I				D
Taneja & Malhotra [111]	Profit			D		
Yusuf & Yusuf [113]	MTSF	I	D			
	Availability	I	D			
	Busy period	D	I			

	Profit	I	D			
Yusuf & Bala [114]	MTSF	I	D			D
Yusuf & Koki, [115]	MTSF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Profit	I	D			
Ali &Yusuf [116]	Availability		D			
	Profit		D			
Munjal & Singh [117]	MTTF	I	D			D
	Profit	I	D			D
Singh et.al. [123]	MTTF	I				
	Availability	I				
	Profit	I	D			
Dalip & Taneja [127]	MTTF	I				
	Profit	I				
Bhardwaj & Singh [128]	MTTF	I	D	D		D
Bhardwaj et.al. [129]	MTTF	I	D			
	Profit	I	D			
Aggarwal et.al. [130]	Availability	I				
Ahmed & Kumar [131]	MTTF	I				
	Profit	I				
El-Damcese & Shama [132]	MTTF	I	D			
	Availability	I	D			
Negi & Singh [134]	MTTF	I				
Babagana et.al. [136]	MTTF	I	D	D		
	Availability	I	D	D		
	Profit	I	D	D		
Ram & Manglik [137]	MTTF	I				
	Profit	I				
Bhatti et.al. [139]	MTTF	I	D		D	D

	Profit	I	D		D	D
Kakkar *et.al.* [139]	MTTF			D		
	Availability			D		
	Busy period			I		
	Number of visits			I		
Kumar & Goel [140]	Availability					D
	Profit					D
Niwas *et.al.*[141]	MTTF					
	Profit					
Niwas *et.al.*[142]	MTTF				D	
	Profit				D	
Sharma & Kaur [143]	Profit	I				D
Sharma & Sharma [144]-[146]	MTTF	I				D
	Profit	I				D
Adlakha et.al.[154]	Profit					D
Ahmed *et.al.* [155] ,[165]	MTTF	I				
	Profit					D
Al Rahbi et.al. [158-163]	MTTF	I	D			
	Availability	I	D			
	Busy Period	D	I			
	Number of visits	D	I			
Mahmoud *et.al.* [169]	Profit					D
Shakuntla et.al.[169]	Availability	I	D			
Mortazavi et.al. [170]	MTTF	I	D			D
Singh *et.al.* [171]	Profit					D
Singh & Ayagi [172]	MTTF	I				
Taj et.al. [173-176]	MTTF	I	D	D		
	Availability	I	D	D		

	Busy period	D	I	I		
	Number of visits	D	I	I		
Taj et.al. [177],[178]	MTTF	I	D			
	Availability	I	D			
	Busy period	D	I			
	Number of visits	D	I			
	Profit	I	D			
Taj et.al. [179]	MTTF	I	D	D		
	Availability	I	D	D		
	Busy period	D	I	I		
	Number of visits	D	I	I		
Abo-Youssef [183]	MTTF	I				
	Availability	I				
Kumar et.al.[184]-[186]	MTTF	I				
	Availability	I				
	Profit	I				
Niwas et.al. [189],[190]	Profit				D	
EL-Bassiouny et.al. [194]	MTTF	I				
Kumar & Kumar [196]	MTTF	I				
	Profit	I				D
Lado and Singh [198]	MTTF	I				
	Availability	I				D
	Profit					
Singh & Poonia [199]	MTTF	I				
	Availability	I				
Yusuf *et.al.* [201]	MTSF	I	D			
	Availability	I	D			
	Profit	I	D			

Gahlot et.al.[204]	MTTF	I				
	Availability	I				
Gupta et.al. [205]	MTTF	I				
Gupta et.al. [206]	MTTF	I				
Bhatti [207]	MTTF	I	D			
	Availability	I	D			
	Profit	I	D		D	D
Jagtap et.al. [208]	Availability	I	D			
Kaur *et.al.* [209]	MTTF	I				
	Profit	I				
Raghav et.al. [210]	MTTF	I				
Jain et.al. [211]	MTTF	I				
	Availability	I				
	Profit	I				
Kadyan et.al. [213]	MTTF		D			
	Availability		D			
	Profit		D			
Poonia & Sirohi [223]	MTTF	I				
	Profit		D			
Yusuf [225]	MTSF			D		
	Availability			D		
Rizwan et.al. [227]	MTTF	I	D			
	Availability	I	D			
	Profit	I				

3. Type of distribution used by various authors for failure rate and repair rate.
Table 2 summarizes the types of distributions used by various authors for failure rate in each reference paper.

Table 2. Behaviour reliability indices with respect to different system parameters

Reference number	Distribution of failure rate	Distribution of repair rate
Usha & Ramanarayanan [8]	Erlang	Erlang
Yamashiro [11]	Exponential	
Goel & Sharma [16]	General	General
Goel & Shrivastava [17]	General	General
Taneja et. al [22]	Exponential	General
Tuteja & Taneja [23]	Exponential	General
Gupta et.al. [24]	General	Exponential
Rajamanickam, S. and Chandrasekar [27]	Marshal Olkin	Marshal Olkin
Rizwan *et.al.* [32],[35]-[39],[41]- [48]	Exponential	General
Ke & Wang [33]	Exponential	Exponential
El-Said &El-Sherbany [40],[66]	General	General
Wang & Chiu [49]	Exponential	General
Nilsson & Bertling [50]	Exponential	
Parshar & Taneja [51]	Exponential	General
Wang et.al. [53]	Exponential	
Al Hemyari & Rizwan [54]	Exponential	Exponential
El-Said &El-Hamid [55]		Exponential
Haggag [56],[57]	Exponential	Exponential
Mathew & Rizwan [65]	Exponential	General
Al-Aamri *et.al.* [68-70]	Exponential	
Al Maqbali *et.al.* [71]	Exponential	
Al-Balushi et.al. [72]	Exponential	
Shakuntla et.al.[73]	General	General
Al Alawi et.al. [74]	Exponential	General
El-Sherbany & El Hussaini [77]		Exponential
Padmavathi et. al [83]-[88]	Exponential	General
Ram et.al. [90]		1)Gumbel Hougaard family of copula

		2)General
Sharma & Kaur [91]	Exponential	General
Yusuf & Hussaini [93]	Exponential	Exponential
Yusuf & Hussaini [94]		Exponential
Bhatti et.al. [95],[96],]207\	Geometric	Geometric
Kadyan [99]	General	General
Kumar & Kapoor [100]		General
Singh & Dubey [110]	Exponential	Gumbel Hougaard family of copula General
Taneja & Malhotra [111]	Exponential	General
Yusuf & Yusuf [113]	Exponential	Exponential
Yusuf & Bala [114]	Exponential	Exponential
Yusuf & Koki, [115] Ali &Yusuf [116]	Exponential General	Exponential General
Soni *et.al.* [121]	Rayleigh	Rayleigh
Dalip & Taneja [126]	Exponential	Arbitrary
Bhardwaj et.al. [128]		Exponential
Bhardwaj et.al. [129]	Geometric	Geometric
Ahmed & Kumar [131]		General
El-Damcese & Shama [132]	Exponential	Exponential
Kumar et.al. [133]	Arbitrary	Arbitrary
Negi & Singh [134]	Exponential	
Ram & Manglik [137]	Exponential	Exponential
Bhardwaj & Singh [138]	General	General
Kumar & Goel [140]	General	General
Rizwan & Taneja [140]	Exponential	General
Niwas *et.al.*[141],[142],[189],[190]	Exponential	General
Sharma & Kaur [143]-[149]	Exponential	General
Ahmed *et.al.* [155] ,[156]		General
Al Rahbi et.al. [158-163]	Exponential	
Bhardwaj et.al. [165]	Weibull	Weibull
Mahmoud *et.al.* [169]	Exponential	General
Singh *et.al.* [171]	Exponential	General
Singh & Ayagi [172] Taj et.al. [173-181]	Exponential Exponential	 General
Abo-Youssef [183]	Exponential	General

Kumar et.al. [184],[185]	Exponential	
Kumar et.al. [186]	Exponential	Arbitrary
Chaowei et.al. [187[	Exponential	
Kumar & Kumar [196]	Exponential	Exponential
Lado and Singh [198]	Exponential	General Gumbel Hougaard family of copula
Singh & Poonia [199]	Exponential	
Yusuf *et.al.* [201]		Exponential
Gupta et.al. [205],[206]	Exponential	Exponential
Kaur *et.al.* [209]	Exponential	General
Raghav et.al. [210]	Exponential	· Gumbel Hougaard family of copula
Jain et.al. [212]	Exponential	Arbitrary
Kadyan et.al. [213]	Exponential	Arbitrary
Singh & Gahlot[216]		Gumbel Hougaard family of copula
Singh et.al. [216]		Exponential
Sharma & Kaur [229]	Exponential	
Mathew et. al [58-64]	Exponential	General
Malhotra & Taneja [102],[104]	Exponential	

The data given in Table II was used to make a summary on preferences given to different type of distribution for failure rate and repair rate by various authors and the following Figure shows the preferences.

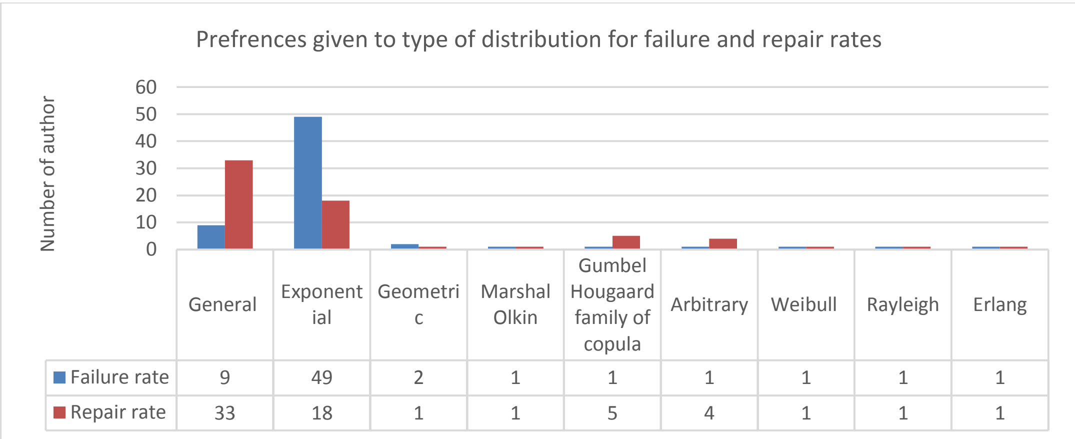

Figure. 1 Preferences given to type of distribution for failure and repair rates

From Figure I, it can be clearly seen that most of the researchers prefer to use exponential distribution for failure rate and general distribution for repair rate.

4. CONCLUSION

The following can be concluded from Table 1, Table 2 and Figure 1,

- MTTF and profit decreases with the increase in the values of the failure rates. On the other hand, the value of MTTF and profit get increased with the increase in the value of repair rate.
- The availability of the system get decreased with increase in the value of the failure rate and it get increased with increase in the value of repair rate, preventative maintenance rate, inspection rate and exchange rate.
- Busy period of the repairman get increased with increase in the value of failure rate. On other it get decreased with increase in the value of repair rate, preventative maintenance rate, inspection rate and exchange rate. Similarly, number of visits by the repairman get increased with increase in the value of failure rate. On other hand, number of visits by the repairman decreases with increase in the value of repair rate, preventative maintenance rate, inspection rate and exchange rate.
- Profit decreases with increase in the value of failure rate. On the contrary, profit increases with increase in the value of repair rate, preventative maintenance rate, inspection rate and exchange rate.
- Majority of the authors used Exponential distribution for failure data and General distribution for the repair data.

5. FUTURE SCOPE

Researchers have contributed immensely to the area of reliability analysis through conventional modeling as shown in this paper, and now is the high time to look for some diversification and use new maintenance models involving probability and fuzzy techniques. New stochastic processes to meet the new requirements for repairable systems at different information levels. New algorithms may be developed for finding the quick solutions rather than using the conventional approaches. Focus on statistical inferences applications on maintenance problems rather than just looking for probability applications would greatly help in arriving to the close approximations to the real outcomes. Statistical application of goodness of fit test can also support the analysis in establishing the robustness of maintenance models. Perspective of using the best-fit distributions while handling the preventive and corrective maintenance strategies need to be strengthened using different available software such as fit-dist.

REFERENCES

[1] Taj, S., Rizwan, S. M. (2019). Reliability modeling and analysis of complex industrial systems – a review. I manager's Journal on Mathematics, 8 (2), pp. 43-60.

[2] Davis, D. An analysis of some failure data. (1952). Journal of the American Statistical Association, 47(258), pp.113-150.

[3] Epstein, B. and Sobel, M. (1955). Sequential life tests in the exponential case. The Annals of Mathematical Statistics, 26(1), pp.82-93.

[4] Gaver, D. (1963). Time to failure and availability of paralleled systems with repair. IEEE Transactions on Reliability, R-12(2), pp.30-38.

[5] Sandler, G. (1963). System Reliability Engineering. Englewood Cliffs, NJ: Prentice-Hall.

[6] Barlow, R. and Proschan, F. (1965). Mathematical theory of reliability. New York: John Wiley & Sons.

[7] Srinivasan, S. and Gopalan, M. (1973). Probabilistic analysis of a two-unit system with a warm standby and a single repair facility. Operations Research, 21(3), pp.748-754.

[8] Ramanarayanan, R. and Usha, K. (1979). N-unit warm standby system with erlang failure and general repair and its dual. IEEE Transactions on Reliability, R-28(2), pp.173-174.

[9] Usha, K and Ramanarayanan, R. (1980). Two n-unit cold-standby systems with an erlang distribution. IEEE Transactions on Reliability, R-29(5), pp.434-435.

[10] Kumar, A. and Agarwal, M. (1980). A review of standby redundant systems. IEEE Transactions on Reliability, R-29(4), pp.290-294.

[11] Yamashiro, M. (1982). A repairable system with n failure modes and k standby units. Microelectronics Reliability, 22(1), pp.53-57.

[12] Gopalan, M. and Naidu, R. (1983). Busy-period analysis of a one-server two-unit system subject to non-negligible inspection time. Microelectronics Reliability, 23(3), pp.453-465.

[13] Rastogi, A., Kumar, A. and Goel, L. (1983). Effect of intermittent repair in a two unit redundant system with standby failure. Microelectronics Reliability, 23(6), pp.1051-1054.

[14] Murari, K., Goyal, V. and Rani, S. (1985). Cost analysis in two-unit warm standby models with a regular repairman and patience time. Microelectronics Reliability, 25(3), pp.473-483.

[15] Yearout, R., Reddy, P. and Grosh, D. (1986). Standby redundancy in reliability - a review, IEEE Transactions on Reliability, 35(3), pp.285-292.

[16] Goel, L. and Sharma, S. (1989). Stochastic analysis of a 2-unit standby system with two failure modes and slow switch. Microelectronics Reliability, 29(4), pp.493-498.

[17] Goel, L., and Shrivastava, P. (1991). Profit analysis of a two-unit redundant system with provision for rest and correlated failures and repairs. Microelectronics Reliability, 31(5), pp.827-833.

[18] Goel L., and Shrivastava, P. (1991). A two unit cold standby system with three modes and correlated failures and repairs, Microelectron Reliability 31(5), pp. 835-840.

[19] Goel L., Shrivastava, P. and Gupta, R. (1992). A two unit cold standby system with correlated failures and repairs, International Journal of Systems Science. 23(3), pp. 379-391,

[20] Gupta, R. and Bansal, S. (1991). Profit analysis of a two-unit priority standby system subject to degradation. International Journal of Systems Science, 22(1), pp.61-72.

[21] Gupta, R. and Goel, R. (1991). Profit analysis of a two-unit cold standby system with abnormal weather condition. Microelectronics Reliability, 31(1), pp.1-5.

[22] Taneja, G., Rizwan, S. M. and Kumar, R. (1992). Profit analysis of a system with perfect repair at partial failure and priority for repair to complete failed unit. Pure and Applied Mathematika Sciences, 35(1/2), pp.131-141.

[23] Tuteja, R. and Taneja, G. (1992). Cost-benefit analysis of a two-server, two-unit, warm standby system with different types of failure. Microelectronics Reliability, 32(10), pp.1353-1359.

[24] Gupta, R., Chaudhary, A. and Goel, R. (1993). Profit analysis of a two-unit priority standby system subject to degradation and random shocks. Microelectronics Reliability, 33(8), pp.1073-1079.

[25] Martin, K. (1994). A review by discussion of condition monitoring and fault diagnosis in machine tools. International Journal of Machine Tools and Manufacture, 34(4), pp.527-551.

[26] Gopalan, M. and Bhanu, K. (1995). Cost analysis of a two unit repairable system subject to on-line preventive maintenance and/or repair. Microelectronics Reliability, 35(2), pp.251-258.

[27] Rajamanickam, S. and Chandrasekar, B. (1997). Reliability measures for two-unit systems with a dependent structure for failure and repair times. Microelectronics Reliability, 37(5), pp.829-833.

[28] Li, W., Alfa, A. and Zhao, Y. (1998). Stochastic analysis of a repairable system with three units and two repair facilities. Microelectronics Reliability, 38(4), pp.585-595.

[29] Tuteja, R., Rizwan, S. M. and Taneja, G. (1999). A two server system with regular repairman, who is not always available. In: 3rd Annual Conference of ISITA and National Symposium on Management Science and Statistics – Applications to Trade & Industry. Amritsar, Punjab, India: pp.231-237.

[30] Tuteja, R., Rizwan, S. M. and Taneja, G. (2000). Profit evaluation of a two unit cold standby system with tiredness and two types of repairman. Journal of

Indian Society of Statistics and Operation Research, 21(1-4), pp.1-10.

[31] Tuteja, R., Rizwan, S. M. and Taneja, G. (2000). Profit analysis of a system with perfect repair at partial or complete failure, Pure and Applied Mathematika Sciences, 52, (2), pp. 7-14.

[32] Rizwan, S. M., Taneja, G. and Tuteja, R. (2000). Comparative study between the profits of two models for a two unit system with rest period of repairman. Journal of Decision and Mathematical Sciences, 5(1-3), pp.27-44.

[33] Ke, J. and Wang, K. (2002). The reliability analysis of balking and reneging in a repairable system with warm standbys. Quality and Reliability Engineering, 18(6), pp.467 – 478.

[34] Kuo, W. and Zuo, M. (2003). Optimal reliability modeling: principles and applications. Hoboken, NJ: John Wiley & Sons.

[35] Rizwan, S. M. and Mohiuddin, A. (2004). Cost benefits analysis of a two unit system with partial failure and alternatives repair facility, Caledonian Journal of Engineering, 1(1), pp.5-7.

[36] Rizwan, S. M. and Mohiuddin, A. (2005). Stochastic Analysis of a System with Critical Human Error Failure" Caledonian Journal of Engineering, 1(3), pp.1-5.

[37] Rizwan, S. M., Garima. , and Mohiuddin, A. (2005). Maintenance Analysis of PLCs, Regional Conference on Maintenance Management, at Caledonian College of Engineering, Sultanate of Oman, 2nd October, 2005, pp 265-270.

[38] Rizwan, S. M., Ramachandran, K.P. and Mohiuddin, A. (2005). Reliability of a Technological System with Rest Period of Repairman, Caledonian Journal of Engineering, 1(4), pp.1-4.

[39] Rizwan, S. M., Chauhan, H. and Taneja, G. (2005). Stochastic analysis of systems with accident and inspection. Emirates Journal of Engineering Research, 10(2), pp.81-87.

[40] El-Said, K. and El-Sherbeny, M. (2005). Profit analysis of a two unit cold standby system with preventive maintenance and random change in units. Journal of Mathematics and Statistics, 1(1), pp.71-77.

[41] Rizwan, S. M., Ramanathan, S. and Mohiuddin, A. (2006). MTSF Analysis of a Two Unit System with Partial Failure Mode" Caledonian Journal of Engineering, 1(2), pp.1-4.

[42] Rizwan, S. M. (2006). Reliability Modeling Strategy of an Industrial System" ISBN: 0-7699-2569-9, in Proceedings of IEEE Conference Publications of Computer Society, First International Conference on Availability, Reliability and Security (ARES'06), Vienna University of Technology, Austria, pp 625-630, 20-22 April 2006. DOI: 10.1109/ARES.2006.

[43] Rizwan, S. M. (2007). Reliability analysis of a two unit system with two repairmen. Caledonian Journal of Engineering, 3(2), pp.1-5.

[44] Rizwan, S. M. (2007). An Industrial Application of Reliability Modeling, International Conference QRM Quality Reliability and Maintenance, University

of Oxford, UK, 22 – 23 March, 2007, pp 247-253.

[45] Rizwan, S. M., Khurana, V. , and Taneja, G. (2005). Reliability modeling of a hot standby PLC system. International Conference on Communication, Computer and Power. Muscat, Sultanate of Oman: pp.486-489.

[46] Rizwan, S. M., Mathew, A.G., Majumdar, G., and Ramachandran, K.(2006). Maintenance Analysis of a Secondary Coating Line Manufacturing Machine,National Conference on Recent Developments and Future Trends in Mechanical Engineering, National Institute of Tech., HP, India, 3-4 Nov 2006, pp 251-257.

[47] Rizwan, S. M., Khurana, V. and Taneja, G. (2007). Modeling and optimization of a single-unit PLC system. International Journal of Modeling and Simulation, 27(4), pp.361-368.

[48] Rizwan, S. M., Khurana, V. and Taneja, G. (2010). Reliability analysis of a hot standby industrial system. International Journal of Modeling and Simulation, 30(3), pp.315-322.

[49] Wang, K. and Chiu, L. (2006). Cost benefit analysis of availability systems with warm standby units and imperfect coverage. Applied Mathematics and Computation, 172(2), pp.1239–1256.

[50] Nilsson, J. and Bertling, L. (2007). Maintenance management of wind power systems using condition monitoring systems—life cycle cost analysis for two case studies. IEEE Transactions on Energy Conversion, [online] 22(1), pp.223-229. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4106011&isnumber=4105991

[51] Parashar, B. and Taneja, G. (2007). Reliability and profit evaluation of a PLC hot standby system based on a master-slave concept and two types of repair facilities. IEEE Transactions on Reliability, 56(3), pp.534-539.

[52] Rizwan, S. M. (2007). Reliability analysis of a two unit system with two repairmen. Caledonian Journal of Engineering, 3(2), pp.1-5.

[53] Wang, K., Ke, J. and Lee, W. (2007). Reliability and sensitivity analysis of a repairable system with warm standbys and R unreliable service stations. International Journal of Advanced Manufacturing Technology, 31(11), pp.1223–1232.

[54] Al Hemyari, Z. and Rizwan, S. M. (2007). Reliability Analysis of a Two Unit System , Caledonian Journal of Engineering, pp.1265-1268

[55] El-Said, K. and El-Hamid, R. (2008). Comparison of reliability characteristics of two systems with preventive maintenance and different modes. Information and Management Sciences, 19(1), pp.107-118.

[56] Haggag, M. (2009). Cost analysis of a system involving common-cause failures and preventive maintenance. Journal of Mathematics and Statistics, 5(4), pp.305-310.

[57] Haggag, M. (2015). Profit analysis and availability of a repairable redundant 3-out-of-4 system involving preventive maintenance. International Journal of Scientific and Engineering Research, 6(8), pp.1161-1173.

[58] Mathew, A.G., Rizwan, S. M., Majumder, M. and Ramachandran, K. (2009). MTSF and availability of a two unit CC plant. In: 3rd International Conference on Modeling, Simulation, and Applied Optimization. Sharjah, UAE: pp.1-6.

[59] Mathew, A.G., Rizwan, S. M., Majumder, M., Ramachandran, K. and Taneja, G. (2009a). Optimization of a single unit CC plant with scheduled maintenance policy. In: 2nd International Conference on Recent Advances in Material Processing Technology. Kovilpatti, TN, India: SME, pp.609-613.

[60] Mathew, A.G., Rizwan, S. M., Majumder, M., Ramachandran, K. and Taneja, G. (2009b). Profit evaluation of a single unit CC plant with scheduled maintenance. Caledonian Journal of Engineering, 5(1), pp.25-33.

[61] Mathew, A.G., Rizwan, S. M., Majumder, M., Ramachandran, K. and Taneja, G. (2010a). Comparative analysis between profits of the two models of a CC plant. In: International Conference on Modeling, Optimization, and Computing. Durgapur, West Bengal, India: AIP, 1298(1), pp.226-231.

[62] Mathew, A.G., Rizwan, S. M., Majumder, M., Ramachandran, K. and Taneja, G. (2010b). Reliability modeling and analysis of a two-unit parallel CC plant with different installed capacities. Journal of Manufacturing Engineering, 5(3), pp.197-204.

[63] Mathew, A.G., Rizwan, S. M., Majumder, M. and Ramachandran, K. (2011). Reliability modelling and analysis of a two unit continuous casting plant. Journal of the Franklin Institute, 348(7), pp.1488-1505.

[64] Mathew, A.G., Rizwan, S. M., Majumder, M., Ramachandran, K. and Taneja, G. (2011). Reliability analysis of an identical two-unit parallel CC plant system operative with full installed capacity. International Journal of Performability Engineering, 7(2), pp.179-185.

[65] Mathew, A.G. and Rizwan, S. M. (2012). Maintenance Analysis of Port PLCs – Case Study, Caledonian Journal of Engineering, 8(2).

[66] El-Said, K. and El-Sherbeny, M. (2010). Stochastic Analysis Of a Two-Unit Cold Standby System with Two-Stage Repair and Waiting Time. The Indian Journal of Statistics, 72(1), pp.1-10.

[67] Malik, S., and Kumar, A. (2010). Probabilistic Analysis of a System with Server Failure During Repair, Journal of Reliability and Statistical Studie,3(1),pp.1-10

[68] Al Amri, S., Mathew, A.G. and Rizwan, S. M. (2011). Reliability Modeling and Analysis of a Refinery Based Centrifugal Pump, Caledonian Journal of Engineering, **7**(1), pp. 38-42.

[69] Al Amri, S., Mathew, A.G. and Rizwan, S. M. (2011). Reliability and Availability Assessment of a Centrifugal Pump', International Conference on Harnessing Technology, Crown Plaza, Sultanate of Oman, pp. 34.

[70] Al-Amri, M., Mathew, A.G. and Rizwan, S. M. (2011). A Probabilistic Analysis of Recycle Gas Compressor', National Symposium on Engineering Final Year Projects, College of Engineering and Architecture, University of Nizwa, Sultanate of Oman.

[71] Al Maqbali, M., Mathew, A.G. and Rizwan, S. (2012). A Probabilistic Risk Analysis of an A.C. Air Compressor (heavy duty)' in Proc. 2nd NSEFYP, 2nd National Symposium on Engineering Final Year Projects, University of Nizwa, Sultanate of Oman.

[72] Al - Balushi, M., Mathew, A.G. and Rizwan, S. M. (2012). Probabilistic Analysis of a Sewage Lifting Centrifugal Pump (Case Study)' in Proc. 2nd NSEFYP, 2nd National Symposium on Engineering Final Year Projects, University of Nizwa, Sultanate of Oman, 15th May 2012.

[73] Shakuntla, S., Lal, A., Bhatia, S. and Singh, J. (2011). Reliability analysis of polytube industry using supplementary variable technique. Applied Mathematics and Computation, 218, pp.3981–3992.

[74] Al Alawi, M., Mathew, A.G., and Collington, J. (2012). Attaining Zero Failure Performance for GIV Gulfstream Aircraft through Reliability Modeling and Analysis. *IJASETR*, **1**(2).

[75] Sharma,U. (2011). Analysis of a Two Unit Standby Oil Delivering System with a Provision of Switching Over to another System at Need to Increase the Availability. Journal of Mathematics and Statistics, 7(1), pp.57–60.

[76] Sharma, U. and Narang, R. (2012). Profit Analysis of a Two Unit Standby Oil Delivering System with Off Line Repair Facility for Partial Failure and Provision of Switching Over

[77] El-Sherbeny, M. and Al-Hussaini, E. (2012). Characteristic reliability measures of mixed standby components and asymptotic estimation. International Journal of Statistics and Applications, 2(3), pp.11-23

[78] Jiang, L., Feng, Q. and Coit, D. (2012). Reliability and maintenance modeling for dependent competing failure processes with shifting failure thresholds. IEEE Transactions on Reliability, 61(4), pp.932-948.

[79] Parashar, B., Naithani, A., and Bhatia, P. (2012) Analysis of a 3-unit induced draft fan system with one warm standby. International Journal of Engineering Science and Technology, 4(11),pp.4620–4628

[80] Parashar, B. and Bhardwaj, N. (2013). A comparative study of profit analysis of two reliability models on a 2-unit PLC system. International Journal of Scientific and Engineering Research, 4(4), pp.400-409.

[81] Kumar, A. and Malik, S.C. (2012). Stochastic Modeling of a Computer System with Priority to PM over S/W Replacement Subject to Maximum Operation and Repair Times. International Journal of Computer Applications, 43(3), pp.27–34.

[82] Suleiman, K. , Ali, A., Bashir. and Yusuf, I. (2012). Measuring the

Effectiveness of a Complex Repairable Series-Parallel System involving Four Types of Failures, International Journal of Basic and Applied Sciences,1(4),pp.523-533

[83] Padmavathi, N., Rizwan, S. M., Pal, A. and Taneja, G. (2012). Reliability analysis of an evaporator of a desalination plant with online repair and emergency shutdowns. Aryabhatta Journal of Mathematics & Informatics, 4(1), pp.1-12.

[84] Padmavathi, N., Rizwan, S. M., Pal, A. and Taneja, G. (2013a). Comparative analysis of the two models of an evaporator of a desalination plant. International Conference on Information and Mathematical Sciences.Bathinda, Punjab, India: pp.418-422.

[85] Padmavathi, N., Rizwan, S. M., Pal, A. and Taneja, G. (2013b). Probabilistic analysis of an evaporator of a desalination plant with priority for repair over maintenance. International Journal of Scientific and Statistical Computing, 4(1), pp.1-8.

[86] Padmavathi, N., Rizwan, S. M., Pal, A. and Taneja, G. (2014a). Probabilistic analysis of a desalination plant with major and minor failures and shutdown during winter season. International Journal of Scientific and Statistical Computing, 5(1), pp.15-23.

[87] Padmavathi, N., Rizwan, S. M., Pal, A. and Taneja, G. (2014b). Probabilistic analysis of a seven unit desalination plant with minor/major failures and priority given to repair over maintenance. Aryabhatta Journal of Mathematics & Informatics, 6(1), pp.219-230.

[88] Padmavathi, N., Rizwan, S. M. and Senguttuvan, A. (2015). Comparative analysis between the reliability models portraying two operating conditions of a desalination plant. International Journal of Core Engineering and Management, 1(12), pp.1-10.

[89] Ram, M. and Singh, S. (2012). Cost benefit analysis of a system under head-of-line repair approach using gumbel-hougaard family copula. Journal of Reliability and Statistical Studies, 5(2), pp.105-118.

[90] Ram, M., Singh, S. and Singh, V. (2013). Stochastic analysis of a standby system with waiting repair strategy. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 43(3), pp.698-707.

[91] Sharma, U. and kaur, J. (2014). Availability Analysis of a Standby System with Three Types of Failure Categories. IOSR Journal of Mathematics, 10(2), pp.23–28.

[92] Sharma, U. and kaur, J. (2014). Comparative Study of Standby Compressor Systems with and without Provision of Priority to Failed Compressor Unit, International Journal of Applied Mathematics & Statistical Sciences,3(6),pp.1-8

[93] Yusuf, I. and Hussaini, N. (2012). Evaluation of reliability and availability characteristics of 2-out of -3 standby system under a perfect repair condition. American Journal of Mathematics and Statistics, 2(5), pp.114-119.

[94] Yusuf, I. and Hussaini, N. (2014). A comparative analysis of three unit redundant systems with three types of failures. Arabian Journal for Science and Engineering, 39(4), pp.3337-3349.

[95] Bhatti, J., Chitkara, A. and Kakkar, M. (2013a). Analysis of Non- Identical System with Two Types of Failure Using Discrete Distribution. Journal of Mathematics, **1**(1), pp.55-62.

[96] Bhatti, J., Chitkara, A. and Kakkar, M. (2013b). Analysis of identical parallel system with failure followed by inspection policy using discrete distribution. International Journal of Scientific & Engineering Research, **4**(5), pp.889-894.

[97] Gupta, S. and Gupta, S. (2013). Stochastic analysis of a reliability model of one-unit system with post inspection, post repair, preventive maintenance and replacement. International Journal of Mechanical Engineering and Robotics Research, 2(2), pp.178-188.

[98] Ibe, O. (2013). Markov processes for stochastic modelling. 2nd ed. London: Elsevier.

[99] Kadyan, M. (2013). Reliability and profit analysis of a single-unit system with preventive maintenance subject to maximum operation time. Maintenance and Reliability, 15(2), pp.176–181.

[100] Kumar, R. and Kapoor, S. (2013). Profit evaluation of a stochastic model on base transceiver system considering software based hardware failures and congestion of calls. International Journal of Application or Innovation in Engineering and Management, 2(3), pp.554-562.

[101] Malhotra, R. and Taneja, G. (2013). Reliability and availability analysis of a single unit system with varying demand. Mathematical Journal of Interdisciplinary Sciences, 2(1), pp.77-88.

[102] Malhotra, R. and Taneja, G. (2013). Reliability Modelling of a Cable Manufacturing System with Inspection and Variation in Demand. International Conference on Information and Mathematical Sciences, pp.196-199.

[103] Malhotra, R. and Taneja, G. (2014). Stochastic analysis of a two-unit cold standby system wherein both units may become operative depending upon the demand. Journal of Quality and Reliability Engineering, [online]. Available at: https://doi.org/10.1155/2014/896379

[104] Malhotra, R. and Taneja, G. (2015a). Comparative analysis of two stochastic models subjected to inspection and scheduled maintenance. International Journal of Software Engineering and its Applications, 9(10), pp.179-188.

[105] Malhotra, R. and Taneja, G. (2015b). Comparative study between a single unit system and a two-unit cold standby system with varying demand. Springer Plus, [online] 4(1). Available at:

https://springerplus.springeropen.com/articles/10.1186/s40064-015-1484-7

[106] Naithani, A., Parashar, B., Bhatia, P. and Taneja, G. (2013). Cost benefit analysis of a 2-out-of-3 induced draft fans system with priority for operation to cold standby over working at reduced capacity. Advanced Modeling and Optimization, 15(2), pp.499-509.

[107] Naithani, A., Parashar, B., Bhatia, P. and Taneja, G. (2017). Probabilistic analysis of a 3-unit induced draft fan system with one warm standby with priority to repair of the unit in working state. International Journal of System Assurance Engineering and Management, 8(S2), pp.1383-1391.

[108] Pathak, V., Mehta, K. and Sahu, S. (2013). Performance analysis of a system having one main unit and two supporting units. International Journal of Mathematics and Computer Research, 1(7), pp.174-188.

[109] Pathak, V., Mehta, K., Sahu, S. and Chaturvedi, R. (2013). Profit analysis of a system having one main unit and two supporting units. International Journal of Engineering and Computer Science, [online] 2(10). Available at: http://www.ijecs.in/index.php/ijecs/article/view/2114.

[110] Singh, R. and Dubey, G. (2013). Reliability and cost analysis of a standby redundant system with critical human errors. International Journal of Engineering and Mathematical Sciences, 4(1), pp.25–33.

[111] Taneja, G. and Malhotra, R. (2013). Cost-benefit analysis of a single unit system with scheduled maintenance and variation in demand. Journal of Mathematics and Statistics, 9(3), pp.155-160.

[112] Yang, Q. Hong, Y. and Zhang, N. (2013). Reliability analysis of repairable systems with dependent component failures under partially perfect repair. IEEE Transactions on Reliability

[113] Yusuf, B. and Yusuf, I. (2013). Evaluation some reliability characteristics of a system under three types of failures with repair-replacement at failure. American Journal of Operational Research, 3(3), pp.83-91.

[114] Yusuf, I. and Bala, S. (2013). Modeling and evaluation of MTSF of a repairable 2-out-of-4 warm standby system attended by repair machines and repairmen. Engineering Mathematics Letters, 2(2), pp.81-89.

[115] Yusuf, I. and Koki, F. (2013). Assessment of profit of a two-stage deteriorating linear consecutive 2-out-of-3 repairable system. Journal of Applied Mathematics and Physics, 1, pp.21-27.

[116] Ali, U. and Yusuf, I. Availability and profit analysis of a linear consecutive 2-out-of-4 repairable system with units exchange. American Journal of Applied Mathematics and Statistics, 2(2), 2014, pp.83-87.

[117] Munjal, A. and Singh, S. (2014). Reliability analysis of a complex repairable system composed of two 2-out-of-3: g subsystems connected in parallel. Journal of Reliability and Statistical Studies, 7, pp.89-111.

[118] Rizwan. S., Thanikal, J. and Torijos, M. (2013). Reliability Analysis of a

Domestic Waste Water Treatment Plant' in Proc. of International Conference on Harnessing Technology, 2-3 Dec 2013, Sultanate of Oman

[119] Rizwan, S. M. and Thanikal, J. (2014). Reliability analysis of a waste water treatment plant with inspection. I-manager's Journal on Mathematics, 3(2), pp.21-26.

[120] Rizwan, S. M., Thanikal, J. and Torrijos, M. (2014). A general model for reliability analysis of a domestic waste water treatment plant. International Journal of Condition Monitoring and Diagnostic Engineering Management, 17(3), pp.3-6.

[121] Soni, K., Singh, U. and Jha, R. (2014). Mathematical analysis of reliability of m out of n warm standby system with repair facilities. International Journal of Advance Research and Innovation, 2(4), pp.744-749.

[122] Yusuf, I., Suleiman, K., Bashir, Y. and Ali, U. (2014). Stochastic modeling and analysis of a repairable 2-out-of-4 system. International Journal of Mathematics in Operational Research, 6(1), pp.23-34.

[123] Singh, V., Rawal, D. and Ram, M. (2014). Modeling and Availability Analysis of Internet Data Center with various Maintenance Policies. International Journal of Engineering, 27(4), pp.599-608.

[124] Pathak, V., Mehta, K., Sahu, S. and Manker, H., (2014a). Mtbf Analysis of the Two-Unit Series System with Repair Facility. International Journal Of Engineering And Computer Science, 3(5), pp.6043-6047

[125] Pathak, V., Mehta, K., Sahu, S. and Manker, H., (2014b). Comparatuve study of Reliability Parameter of a System under different types of distributuin functions. African Journal of Mathematics and Computer Science Research, 7(4), pp.47-54

[126] Dalip, S. Taneja, G. (2014). Reliability and Economic Analysis of a Power Generating System Comprising One Gas and One Steam Turbine with Random Inspection. Journal of Mathematics and Statistics, 10(4), pp.436-442

[127] Li, L., Jia, L. and Wang, Y. (2014). Reliability Model Construction for Complex System Based on Common Cause Failure Network. Advances in Multimedia, 2014, pp.1–7.

[128] Bhardwaj RK, Singh R (2014) Semi Markov approach for asymptotic performance analysis of a standby system with server failure. International Journal of Computer Application 98(3), pp. 9-14.

[129] Bhardwaj, N., Bhatti, J., Parashar, B., and Sharma, N. (2015). Stochastic analysis of standby system with different failure. International Journal of Applied Engineering Research,**10**(35), pp.27553-27563.

[130] Aggarwal, A., Kumar, S., and Singh, V. (2015). Mathematical modeling and reliability analysis of the serial processes in feeding system of a sugar plant, *International Journal of System Assurance Engineering and Management*, [online] available at http:// DOI 10.1007/s13198-015-0360-8

[131] Ahmad, S. and Kumar, V. Profit analysis of a two-unit centrifuge system considering the halt state on occurrence of minor/ major fault. (2015). International Journal of Advanced Research in Engineering and Applied Sciences, 4(4), pp.94-108.

[132] El-Damcese, M., and Shama, M. (2015). Reliability and availability analysis of a 2-state repairable system with two types of failure. Engineering Mathematics Letters, [online] 2015. Available at: http://scik.org/index.php/eml/article/view/2030

[133] Kumar, A., Baweja, S. and Barak, M. (2015). Stochastic behavior of a cold standby system with maximum repair time. Decision Science Letters, 4, pp.569–578.

[134] Negi, S. and Singh, S. (2015). Reliability analysis of non-repairable complex system with weighted subsystems connected in series. Applied Mathematics and Computation, 262, pp.79–89.

[135] Rizwan, S. M. and Mathew, A.G. (2015). Performance analysis of port cranes. International Journal of Core Engineering and Management, 2(1), pp.133-140.

[136] Babagana, M., Gimba, B. and Yusuf, Introducing probabilistic models for redundant system reliability. *Operations Research and Decisions,* **26**(1), 2016, pp.5-18.

[137] Ram, M. and Manglik, M. (2016). Stochastic Biometric System Modelling with Rework Strategy. International Journal of Mathematical, Engineering and Management Sciences, 1(1), pp.1–17.

[138] Bhardwaj, R. and Singh, R. (2016). Stochastic model of a cold-standby system with waiting for arrival and treatment of server. American Journal of Operations Research, 6, pp.334-342.

[139] Kakkar, M.,Chitkara, A. and Bhatti, J. (2016). Reliability analysis of two dissimilar parallel unit repairable system with failure during preventive maintenance. Management Science Letter, 6(4), pp.285-296.

[140] Kumar, J. and Goel, M. (2016). Availability and profit analysis of a two-unit cold standby system for general distribution. Cogent Mathematics, [online] 3(1). Available at: https://doi.org/10.1080/23311835.2016.1262937

[141] Niwas, R., Kadyan, M. and Kumar, J. (2015). Probabilistic analysis of two reliability models of a single-unit system with preventive maintenance beyond warranty and degradation. Ekspolatacja i Niezawodnosc - Maintenance and Reliability, 17(4), pp.535–543.

[142] Niwas, R., Kadyan, M. and Kumar, J. (2016). MTSF (mean time to system failure) and profit analysis of a single-unit system with inspection for feasibility of repair beyond warranty. International Journal of System Assurance Engineering and Management, 7(1), pp.198-204.

[143] Sharma, U. and Kaur, J. (2016a). Cost benefit analysis of a compressor standby system with preference of service, repair and replacement is given to recently

failed unit. International Journal of Mathematics Trends and Technology, 30(2), pp.104-108.

[144] Sharma, U. and Sharma, G. (2016a). Probabilistic analysis of a standby system with provision of concomitant working. International Journal of Engineering Trends and Technology, 40(1), pp.31-34.

[145] Sharma, U. and Sharma, G. (2016b). COMPARATIVE STUDY OF TWO STANDBY INNOVATIVE SYSTEMS WHERE OPERATION OF ALL STANDBY UNITS IS NECESSARY ON THE FAILURE OF MAIN UNIT. International Journal of Engineering, Science and Research Technology,5(2),pp.68-71

[146] Sharma, U. and Kaur, J. (2016b). Comparative Study of Two Standby Systems with Concept of Priority to Failed Unit. International Journal of Science, Engineering and Technology Research,5(4),pp.85-89

[147] Sharma, U. and Kaur, J. (2016c). Evaluation of Various Reliability Measures of Three Unit Standby System Consisting of One Standby Unit and One Generator. International Journal of Industrial Engineering, 3(2), pp.140-144.

[148] Sharma, U. and Kaur, J. (2016d).Study of Two Units Standby System with One Essential Unit to Increase Its Functioning. International Journal of Engineering Trends and Technology,33(11),pp.97-100.

[149] Sharma, U. and Kaur, J. (2016e).Profit Evaluation of Three Units Compressor Standby System. International Journal of Advanced Research Trends in Engineering and Technology, 3(5),pp.90-94.

[150] Singh, V., Gulati, J., Rawal, D. and Goel, C. (2016). Performance analysis of complex system in series configuration under different failure and repair discipline using copula. International Journal of Reliability, Quality and Safety Engineering, [online] 23(2). Available at:https://doi.org/10.1142/S0218539316500108.

[151] Taneja, G., Malhotra, R. and Chitkara, A. (2016). Comparative profit analysis of two reliability models with varying demand. Aryabhatta Journal of Mathematics & Informatics, 8(2), pp.305-314.

[152] Taneja, G., Malhotra, R. and Chitkara, A. (2016). Comparative profit analysis of two reliability models with varying demand. Aryabhatta Journal of Mathematics & Informatics, 8(2), pp.305-314.

[153] Zio, E. (2016). Some challenges and opportunities in reliability engineering. IEEE Transactions on Reliability, 65 (4), pp.1769-1782.

[154] Adlakha, N., Taneja, G. and Shilpi . (2017). Reliability and cost-benefit analysis of a two-unit cold standby system used for communication through satellite with assembling and activation time. International Journal of Applied Engineering Research, 12(20), pp.9697-9702.

[155] Ahmad, S., Sharma, G. and Sharma, U. (2018a). Reliability Analysis of a Parallel Unit System with Two Cold Standby Units. International Journal of

Advanced Research in Engineering& Management, 4(12), pp.12–18

[156] Ahmad, S., Sharma, G. and Sharma, U. (2018b). Modelling and Profit Evaluation of a Repairable System Working with One Operative Unit and Three Cold Standby Units. International Journal of Mathematics Trends and Technology, **64**(1), pp.65–71.

[157] Lado, A.K., Singh, V.V. (2019) Cost Assessment of complex repairable system consisting two subsystems in Series configuration using Gumbel Hougaard family copula. International Journal of Quality and Reliability Management, 36(10),pp.1683–1698

[158] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G. (2017a). Reliability analysis of a subsystem in aluminum industry plant. In: 6thInternational Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions. [online] Noida, UP, India: IEEE, pp. 199-203. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8342424&isnumber=8342379

[159] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G. (2017b). Reliability analysis of rodding anode plant in aluminium industry. *International Journal of Applied Engineering Research*, **12**(16), 2017b, pp.5616-5623.

[160] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G.(2018a),.Maintenance analysis of a butt thimble removal station in aluminium plant. *International Journal of Mechanical Engineering and Technology*, **9**(4),pp. 695-703.

[161] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G. (2018b). Reliability analysis of rodding anode plant in an aluminum industry with multiple repairmen. *Advances and Applications in Statistics*, **53**(5), pp.569-597.

[162] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G. (2019a). Reliability analysis of a rodding anode plant in aluminum industry with multiple units failure and single repairman. International Journal of System Assurance Engineering and Management, **10**(1), pp.97-109.

[163] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G.(2019b). Reliability analysis of multiple units with multiple repairmen of rodding anode plant in aluminum industry. Advances and Applications in Statistics, 54(1), pp.151-178.

[164] Al Rahbi, Y., and Rizwan, S. M. (2020). A Comparative Analysis between the Models of a Single Component with Single Repairman & Multiple Repairmen of an Aluminium Industry, International Conference on Computational Performance Evaluation , North-Eastern Hill University, Shillong, Meghalaya, India. Jul 2-4.

[165] Bhardwaj, R., Kaur, K. and Malik, S. (2017). Reliability indices of a redundant

system with standby failure and arbitrary distribution for repair and replacement times. International Journal of System Assurance Engineering and Management, 8(2), pp.423-431.

[166] Fagge, N., Yusuf, I. and Ali, U. (2017). Availability evaluation of repairable system requiring two types of supporting device for operations. International Journal of Applied Mathematical Research, 6(1), pp.14-19.

[167] Goyal, S. and Malhotra, R. (2017). A systematical study of reliability on various models. International Journal of Advance Research in Science and Engineering, 6(4), pp.864-876.

[168] Keleş, B., Tekin, S. and Bakır, N. (2017). Maintenance policies for a deteriorating system subject to non-self-announcing failures. IEEE Transactions on Reliability, [online] 66(1), pp.219-232.

[169] Mahmoud, M., Haggag, M. and Abd-Elghany, A. (2017). Stochastic analysis of a duplicated standby system subject to shocks during repair. Journal of the Egyptian Mathematical Society, 25(2), pp.186-190.

[170] Mortazavi, S., Karbasian, M. and Goli, S. (2017). Evaluating MTTF of 2-out-of-3 redundant systems with common cause failure and load share based on alpha factor and capacity flow models. International Journal of System Assurance Engineering and Management, 8(3), pp.542-552.

[171] Singh, N., Singh, D. and Saini, A. (2017). Cost-benefit analysis of two non-identical units cold standby system subject to heavy rain with partially operative after repair. Global Journal of Pure and Applied Mathematics, 13(2), pp.137-147.

[172] Singh, V. and Ayagi, H. (2017). Study of reliability measures of system consisting of two subsystems in series configuration using copula. Palestine Journal of Mathematics, 6(2), pp.102-111.

[173] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2017a). Probabilistic modelling and analysis of a cable plant subsystem with priority to repair over preventive maintenance, i-manager's Journal on Mathematics, 6(3), pp.12-21.

[174] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2017b). Reliability analysis of a single machine subsystem of a cable plant with six maintenance categories. International Journal of Applied Engineering Research, 1(8), 1752-1757.

[175] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2017c). Reliability modeling and analysis of a single machine subsystem of a cable plant. In: 7thInternational Conference on Modeling, Simulation, and Applied Optimization. [online] Sharjah, UAE: IEEE, pp.1-4. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7934917&isnumber=7934840

[176] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2018a).

Comparative analysis of reliability models of a cable plant portraying summer and winter operating strategy. In: 9thInternational Conference on Quality, Reliability, Infocom Technology and Business Operations. Delhi, India: Springer.

[177] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2018b). Performance analysis of a rod breakdown system. International Journal of Engineering and Technology, 7(3.4), pp.243-248.

[178] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2018c). Performance and cost benefit analysis of a cable plant with storage of surplus produce. International Journal of Mechanical Engineering and Technology, 9(8), pp.814-826.

[179] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2018d). Profit analysis of a cable manufacturing plant portraying the winter operating strategy. International Journal of Mechanical Engineering and Technology, 9(11), pp.370-381.

[180] Taj, S., Rizwan, S. M., Alkali, B., Harrison, D. and Taneja, G. (2018e). Reliability analysis of a 3-unit subsystem of a cable plant. Advances and Applications in Statistics, 52(6), pp.413-429.

[181] Taj, S., Rizwan, S. M. and Taneja, G. (2018). Reliability analysis of a wire drawing system with mandatory rest period. International Journal of Mechanical Engineering and Technology, 9(4), pp.1–10.

[182] El-Damcese, M., and Shama, M. (2018). Reliability Analysis of a New k-out-of-n: G Mode. World journal of modeling and simulation. pp.3-17

[183] Abo-Youssef, S.E. and Assed, F.A. (2018). Stochastic Analysis of Two Non-identical Unit Parallel System Incorporating Waiting Time and Preventive Maintenance. Journal of Advance Mathematics, **14**(2), pp.7946–7964.

[184] Kumar, A., Saini, M. and Devi, K.(2018). Stochastic modeling of non-identical redundant systems with priority, preventive maintenance, and Weibull failure and repair distributions. Life Cycle Reliability and Safety Engineering, 7(2), pp.61-70.

[185] Kumar, A., Pawar, D. and Malik, S.C. (2019a). Profit analysis of a warm standby non-identical unit system with single server performing in normal/abnormal environment. Life Cycle Reliability and Safety Engineering, 8(3), pp.219–226.

[186] Kumar, A., Pawar, D. and Malik, S.C. (2019b). Profit analysis of a warm standby non-identical unit system with single server subject to preventive maintenance, International Journal of Agriculture and Statistical Science,15(1),pp.261-269

[187] Chaowei, W., Xun, H., Qian, W., Yutao, Q., & Yuanyuan, F. (2019). Study on Reliability Calculation of Repairable System Based on Monte-Carlo Simulation. Journal of Physics: Conference Series, *1284*, 012009.

https://doi.org/10.1088/1742-6596/1284/1/012009

[188] Bhardwaj, S. Bhardwaj, N. and Kimar, V. (2019). The study of reliability of Diesel Locomotive Engine using Weibull distribution. Int. J. Agricult. Stat. Sci., **15**(2), pp. 549-554.

[189] Niwas, R. and Garg, H. (2018a). An approach for analyzing the reliability and profit of an industrial system based on the cost free warranty policy. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 40(5).

[190] Niwas, R. and Kadyan, M.S. (2018b). Stochastic analysis of a single-unit system with repairman having multiple vacations. INTERNATIONAL JOURNAL OF COMPUTER APPLICATION, 1(8).

[191] Sharma, U. and Sharma, G. (2018a). Semi-markov model for a power plant system comprising of three low pressure boilers and fans. International Journal of Research in Advent Technology, 6(7),pp.13965-1398

[192] Sharma, U. and Sharma, G. (2018b). Performance Analysis of a High Pressure Boiler with Two Low Pressure Boilers: A Cold Standby System. International Journal of Scientific Research and Reviews, 7(3), 694-703.

[193] Sharma, U. and Sharma, G. (2018c). A study of a parallel fan standby redundant system operating in a power plant. International Journal of Advanced Scientific Research and Management, 3(8),pp.233-237.

[194] EL-Bassiouny, A.A., EL-Shimy, M. and Hamouda, R. (2019). Probabilistic Analysis of the Reliability Performance for Power Transformers in Egypt. Renewable Energy and Sustainable Development, 5(2), p.46.

[195] Kakkar, M., Bhatti, J., Malhotra, R. , Kaur, M., and Goyal, D. (2019). Availability Analysis of an Industrial System under the Provision of Replacement of a Unit using Genetic Algorithm. International Journal of Innovative Technology and Exploring Engineering, 9(1), pp. 1236-1241

[196] Kumar, P., & Kumar, A. (2019). Reliability Analysis of an Industrial System under Cost-Free Warranty and System Rest Policy. Journal of KONBiN, 49(2), pp.377–395.

[197] Kumar, P., & Kumar, A. (2020). Analysis of various reliability parameters for rice industry. Journal of Physics: Conference Series. [online] Available at: https://iopscience.iop.org/article/10.1088/1742-6596/1531/1/012065 [Accessed 19 Jan. 2021].

[198] Lado, A.K., Singh, V.V. (2019) Cost Assessment of complex repairable system consisting two subsystems in Series configuration using Gumbel Hougaard family copula. International Journal of Quality and Reliability Management, 36(10),pp.1683–1698

[199] Singh, V., and Poonia, P. (2019). Probabilistic Assessment of Two-Unit Parallel System with Correlated Lifetime under Inspection Using Regenerative Point Technique. International Journal of Reliability, Risk and Safety: Theory and

Application, 2(1), pp.5–14.

[200] Sayed, A., El-Shimy, M., El-Metwally, M. and Elshahed, M. (2019). Reliability, Availability and Maintainability Analysis for Grid-Connected Solar Photovoltaic Systems. Energies, 12(7), p.1213.

[201] Yusuf, I., Yusuf, B. and Sani, B. (2019). Profit Analysis of a Serial-parallel System under Partial and Complete Failures. Journal of Applied Sciences,19(6),pp.565-574

[202] Yusuf, I., Yusuf, B. and Suleiman, K. (2019). Reliability assessment of a repairable system under online and offline preventive maintenance. Life Cycle Reliability and Safety Engineering, 8(4), pp.391–406.

[203] Yusuf, I., Ismail, A. and Ali, U. (2020). Reliability analysis of communication network system with redundant relay station under partial and complete failure. (2020). Journal of Mathematical and Computational Science, 10(4),pp. 863-880.

[204] Gahlot, M., Singh, V.V., Ayagi, Hamisu.I., and Abdullahi, I. (2019). Stochastic analysis of a two units' complex repairable system with switch and human failure using copula approach. Life Cycle Reliability and Safety Engineering, 9(1), pp.1–11.

[205] Gupta, N., Saini, M. and Kumar, A. (2020). Behavioral Analysis of Cooling Tower in Steam Turbine Power Plant using Reliability, Availability, Maintainability and Dependability Investigation. Journal of Engineering Science and Technology Review, 13(2), pp.191–198.

[206] Gupta, N., Kumar, A. and Saini, M. (2021). Reliability and Maintainability Investigation of Generator in Steam Turbine Power Plant using RAMD analysis. Journal of Physics: Conference Series, 1714, p.012009.

[207] Bhatti, J. (2020). Reliability Annalysis to Industrial Active Standby Rendundant System. Malaysian Journal of Science, 39(3), pp.74-84.

[208] Jagtap, H.P., Bewoor, A.K., Kumar, R., Ahmadi, M.H., El Haj Assad, M. and Sharifpur, M. (2020). RAM analysis and availability optimization of thermal power plant water circulation system using PSO. Energy Reports.

[209] Kaur, R., Ahmad, S. and Sharma, U. (2020). Reliability Modelling of a Gravity Die Casting System Covering Seven Types of Failure Categories. International Journal of New Innovations in Engineering and Technology, 12(4), pp.107–111.

[210] Raghav, D., Poonia, P., Gahlot, M., and Singh, V. (2020). Probabilistic analysis of a system consisting of two subsystems in the series aof configuration under copula repair approach, J. Korean Soc. Math. Educ. Ser. B: Pure Appl. Math,27(3).

[211] Sanusi, A. and Yusuf, I. (2020). Cost analysis of 2-out-of-4 system connected to two-unit parallel supporting device for operation. Life Cycle Reliability and Safety Engineering.[online]. Available at https://doi.org/10.1007/s41872-020-

00134-z.
[212] Jain, P., Pawar, D., and Malik, S.C. (2020). Reliability Measures of a 1-Out-of-2 System with Standby and Delayed Service. International Journal of Mechanical and Production Engineering Research and Development, 10(3), pp.12725–12732.
[213] Kadyan, S., Malik, S. and Gitanjali, (2021). Stochastic Analysis of a Three-Unit Non-Identical Repairable System with Simultaneous Working of Cold Standby Units. Journal of Reliability and Statistical Studies.
[214] Singh, V., and Gahlot, M.(2020). Stochastic Analysis of Complex System with Auto Changeover Switch and Advert Environment Employing Copula Approach. International Journal of Reliability, Risk and Safety,3(1),pp.17-26.
[215] Singh, V., Poonia, P. and Rawal, D., (2020). Reliability analysis of repairable network system of three computer labs connected with a server under 2- out-of- 3 G configuration. Life Cycle Reliability and Safety Engineering.
[216] Singh, V., Poonia, P. and Abdullahi, A. (2020). Performance analysis of a complex repairable system with two subsystems in series configuration with an imperfect switch. Journal of Mathematics and Computer Science,10(2),pp.359-383
[217] Singh, V.V., Lado Ismail, A.K., Yusuf, I. and Abdullahi, A.H. (2021). Probabilistic Assessment of Computer-Based Test (CBT) Network System Consists of Four Subsystems in Series Configuration Using Copula Linguistic Approach. Journal of Reliability and Statistical Studies.
[218] Kumar, A. Pawar, D., and Malik, S.C. (2020). Reliability Analysis of a Redundant System with 'FCFS' Repair Policy Subject to Weather Conditions, International Journal of Advanced Science and Technology, 29(3), pp. 7568 - 7578
[219] Kumar, A. Singh, R. Saini, M. and Dahiy, O. (2020). Reliability, Availability and Maintainability Analysis to Improve the Operational Performance of Soft Water Treatment and Supply Plant. JOURNAL OF Engineering Science and Technology Review, 13(5, pp.83-19.
[220] Malhotra, R. and Dureja, T. (2021). Reliability modelling of a two unit cold standby system working in a pharmaceutical company with rest period and varying demand. Journal of Physics Conference. IOP Conference series.
[221] Saini, M., Goyal, D., Kumar, A. and Sinwar, D. (2021). Investigation of performance measures of power generating unit of sewage treatment plant. Journal of Physics: Conference Series, 1714, p.012008.
[222] Taj, S. Z., Rizwan, S. M. M., Alkali, B. M., Harrison, D. K. & Taneja, G. (2020). Three reliability models of a building cable manufacturing plant: a comparative analysis. International Journal of Systems Assurance Engineering and Management. doi: 10.1007/s13198-020-01012-8
[223] Poonia, P., Sirohi, A. (2020). Cost Benefit Analysis of a k-out-of-n: G Type

Warm Standby Series System under Catastrophic Failure Using Copula Linguistics. International Journal of Reliability, Risk and Safety: 3(1), pp.35-44.

[224] Poonia, P., Sirohi, A. and Kumar, A., (2021). Cost analysis of a repairable warm standby k-out-of-n: G and 2-out-of-4: G systems in series configuration under catastrophic failure using copula repair. Life Cycle Reliability and Safety Engineering

[225] Yusuf, I. (2016). Reliability modeling of a parallel system with a supporting device and two types of preventive maintenance. International Journal of Operational Research, 25(3), pp.269-287.

[226] Yusuf, I., Ismail, A., Singh, V., Ali, U. and Sufi, N., (2020). Performance Analysis of Multi-computer System Consisting of Three Subsystems in Series Configuration Using Copula Repair Policy. SN Computer Science, 1(5).

[227] Rizwan, S. M., Thanikal, J., Padmavathi, N. and Yazidi, H. (2015). Reliability & availability analysis of an anaerobic batch reactor treating fruit and vegetable waste. International Journal of Applied Engineering Research, 10(24), pp.44075- 44079.

[228] Sharma, U. and Sharma, G. (2018).Steady State Behaviour of a Cold Standby System Consisting of Turbine, Boiler and Fans. IOSR Journal of Engineering,8(8),pp.224-230

[229] Sharma, U. and Kaur, J. (2018). On Expected Profit of Four Compressor Units Standby System with Priority to Recently Failed Unit. International Journal of Interdisciplinary Research and Innovations, 6(3),pp. 237-246.