Reliability Allocation and Optimization Problem for Waste Treatment Plant (WTP)

Saad Abbas Abed[1]	Department of computer, College of Education, AL-Iraqia University, Iraq. saadaaa2013@yahoo.com.
Mahmood S. Fiadh[2]	Department of computer, College of Education, AL-Iraqia University, Iraq. salim_fa@yahoo.com.
Ahmed Hussein Ali[3]	Department of computer, College of Education, AL-Iraqia University, Iraq ahmed.ali@aliraqia.edu.iq

The issue of waste treatment is one of the topics that have a direct impact on the environment and human life. In previous studies the mathematical model of waste treatment has proven its importance for large-scale waste treatment plant (WTP). Little experience has been gained in mathematical modeling of waste treatment plant. In this study an optimal waste treatment plant system (WTPS) was identified, a non-linear programming model was applied to assign reliability to the system. The problem was formulated as a non-linear programming as the C.F is the target function (which depends on the reliability of the system) as well as the reliability of the waste treatment plant system as a constraint function. The (O.P) has been solved to allocate reliability requirements by using one of the optimization methods Cukoo Optimization Algorithm (C.O.A). Important results have been reached to allocate the reliability of each component of the system used in our study at appropriate costs, which may help researchers in the future to find better ways to solve the problem of optimal reliability of the aforementioned system above

(i) The system used in this paper is (W. T. P) system with the C.F.

(ii) The results obtained were by using the (C .O .A) to solve specific system (R.O.P).

Keywords: Reliability network, Reliability Optimization problem (R.O.P), Reliability allocation (R.A), Cukoo Algorithm (C.A), Waste Treatment Plant (W.T.P), Cost function (C.F), Optimization Problem(O.P).

1. Introduction

The waste treatment plant system (WTPS) is a system made up of components or subsystems connected with each other in a series-parallel system, through which the collection, storage, transport, treatment and landfill of wastes are controlled according to certain principles that take into account the environment, health and economy by recycling these wastes using the modern scientific techniques, conservation of resources, aesthetics and the environment [15]. Many researchers have dealt with the (WPTS) study of the waste treatment system, such as Powell JC and others [16], and given the characteristics of this topic are concentrated in terms of geometrical, economics, environment and science, the researchers have dealt with re-highlighting it by many researchers such as, Ghiani G, Laganà D , Manni E, Musmanno R, Vigo D. [6], and Yu H, Solvang WD, Li S.[18] the researchers discussed the optimization problem of this system. The researcher (Abed, S. A.)[1-3],[19],[24], also discussed the issue of (R.O.P) of this system in general as series-parallel system. This paper focuses on the problem of (R.A.P) as a mathematical problem (non-linear programming) although its engineering roots are as a design issue, where the issue was formulated as the (C.F) is a function of the objective and the reliability of the system used as the constraints of that problem,[7-11], [17]. The C.F contains many parameters in the proposed C.F according to the business requirements or the actual need for the system to function well, this matter will make researchers have several scenarios to formulate the allocation problem in order to obtain appropriate reliability and lowest costs. In this paper the use of the (logarithmic C.F) is mimetically increasing [4],[5]. Also, the results obtained after solving the optimization reliability problem (O.R.P) using the (C.A) contributed to improving the reliability of the system at reasonable costs. The method (C.A) is considered one of the important methods of optimization methods, which have been applied and used by many researchers, as it is characterized by the accuracy of the solution, the speed of achievement, the shortening of time and effort, as well as it can be applied to the constrained and unrestricted problems in optimization, and for these reasons, this method was adopted in our research to find the solution for the system the user [23],.

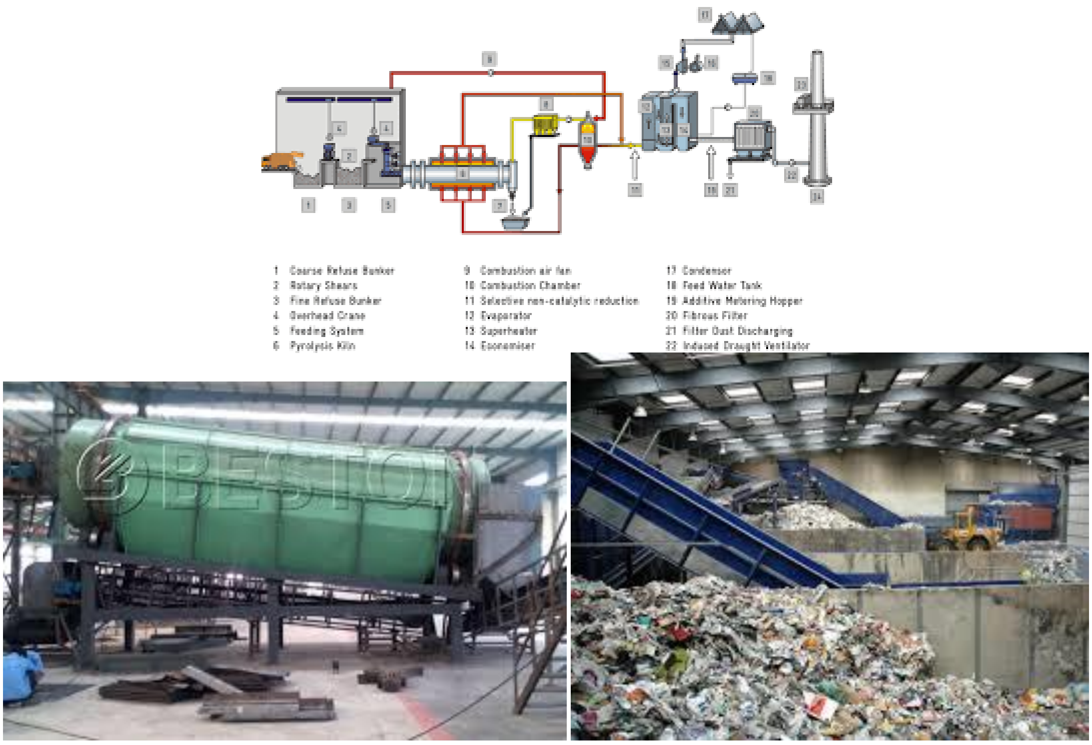

Fig.1 Present of Solid Waste Treatment

2. Reliability function and reliability importance for (W.T.P)

In this paper, we used the path tracing method it is one of the methods used to find reliability system, In the waste treatment plant system (WTPS) consists of 6 subsystems (stages) as shown in Fig. (2) as the components of this system are related to each other according to the series-parallel system, and the main goal is to calculate the reliability of the above[20]. The system by assigning the reliability of each of its six subsystems and thus calculating the lowest costs as the problem will be according to non-linear programming [2].

$\mathcal{R}_s = \prod_{i=1}^{m} \mathcal{R}_i = \prod_{i=1}^{m} [1-(1-r_i)^{c_i}] \geq \mathcal{R}_T, 0 < r_i \leq 1, i = 1,2,\dots,m.$

Where r_i: the reliability of component *i*, $\mathcal{R}_T$: *the reliability goal.*

Let $\mathcal{R}_i = 1-(1-r_i)^{c_i}$, after reducing the system, the number of subsystems will be 3 linked with each other according to the series system as shown in the Fig. (4).

$\mathcal{R}_1 = r_1.r_2$, $\mathcal{R}_2 = 1-(1-r_3)(1-r_4)(1-\ r_5)$, $\mathcal{R}_3 = r_6$.

Then the reliability equation of (WTPS) is:

$\mathcal{R}_s = r_2.r_5.r_6 + r_1.r_2.r_4.r_6 - r_2.r_4.r_5.r_6 + r_1.r_2.r_3.r_6 - r_1.r_2.r_3.r_5.r_6 - r_1..r_3.r_4.r_6 + r_1.r_2.r_3.r_4.r_5.r_6$.

Case1: if all components are identical ($r_{1=}r_2 = r_3 = r_4 = r_5. = r_6 = r$), then the reliability system is:

$\mathcal{R}_s = 3r^4 - 3\,r^5 + r^6$, before starting to solve the fitness problem, we must verify the importance of reliability (R.I) for each of the six components, as the (R.I) will be compute by using the following equation [1]:

$$I_{\mathcal{R}}(i) = \frac{\partial \mathcal{R}_s}{\partial \mathcal{R}_i}.$$

The (R.I) for each component of the system, as shown in the following equations:

$\frac{\partial \mathcal{R}_s}{\partial r_1} = r_2.r_5.r_6 + r_2.r_4.r_6 - r_2.r_4.r_5.r_6 + r_2.r_3.r_6 - r_2.r_3.r_5.r_6 - r_2.r_3.r_4.r_6 + r_2.r_3.r_4.r_5.r_6$.

$\frac{\partial \mathcal{R}_s}{\partial r_2} = r_1.r_5.r_6 + r_1.r_4.r_6 - r_1.r_4.r_5.r_6 + r_1.r_3.r_6 - r_1.r_3.r_5.r_6 - r_1.r_3.r_4.r_6 + r_1.r_3.r_4.r_5.r_6$.

$\frac{\partial \mathcal{R}_s}{\partial r_3} = r_1.r_2.r_6 - r_1.r_2.r_5.r_6 - r_1.r_2.r_4.r_6 + r_1.r_2.r_4.r_5.r_6$.

$\frac{\partial \mathcal{R}_s}{\partial r_4} = r_1.r_2.r_6 - r_1.r_2.r_5.r_6 - r_1.r_2.r_3.r_6 + r_1.r_2.r_3.r_5.r_6$.

$\frac{\partial \mathcal{R}_s}{\partial r_5} = r_1.r_2.r_6 - r_1.r_2.r_4.r_6 - r_1.r_2.r_3.r_6 + r_1.r_2.r_3.r_4.r_6$.

$\frac{\partial \mathcal{R}_s}{\partial r_6} = r_1.r_2.r_5 + r_1.r_2.r_4 - r_1.r_2.r_4.r_5 + r_1.r_2.r_3 - r_1.r_2.r_3.r_5 - r_1.r_2.r_3.r_4. + r_2.r_3.r_4.r_5.r_6$.

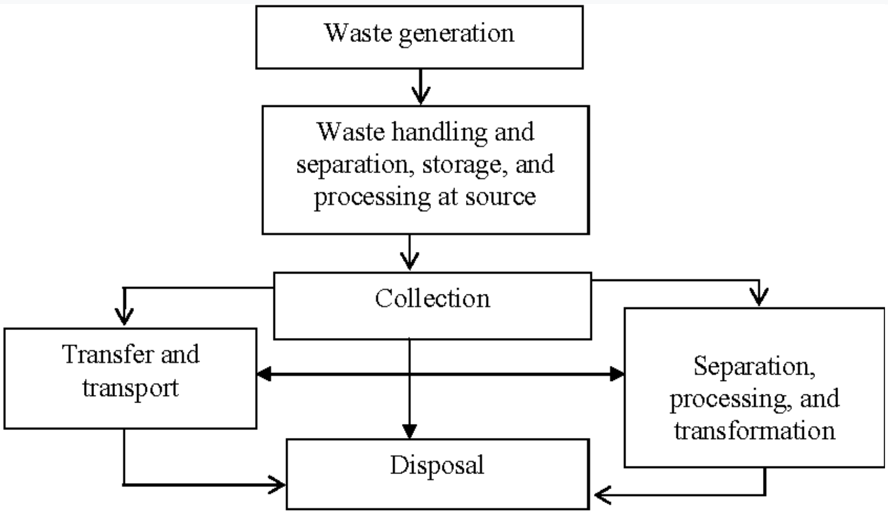

Fig.2 Present System of Waste Treatment

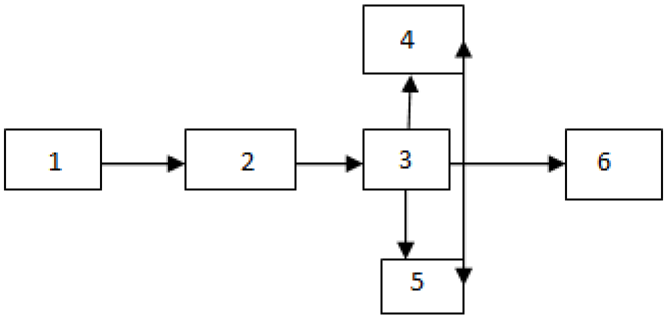

Fig.3 Illustrative diagram of the stages of the waste treatment system

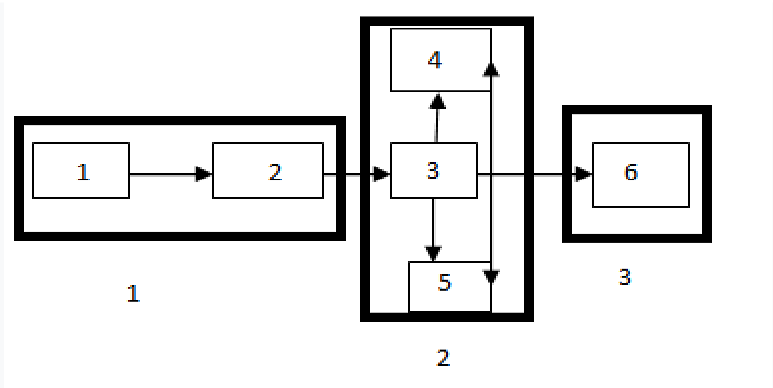

Fig.4 Present system of waste treatment after reduction

3. Optimization for waste treatment plant

The reliability design problem is very similar to the mathematical model of the industrial waste design problem for a treatment plant. In fact, the aforementioned system design includes the processing units connected to each other in a series [12-14], The cost for each component (*i-th*) has the form:

$$C_i = k_i[1-(1-r_i)^{x_i}]^{c_i}, i = 1, \dots, n,$$

where C_i is the total cost, $k_i > 0$, c_i is a fixed exponent, s_i is reliability of i-th component, x_i = number of components in stage i . As for the system design problem shown above, it consists of several dependencies distributed over each of the n components and $r = (r_1, \dots, r_n)$, miniaturization. Therefore, the optimization R.A problem can be formulated as follows [2]:

$$\min_{r} \sum_{i=1}^{m} k_i[1-(1-r_i)^{x_i}]^{c_i}$$

Subject to

... (1)

$$\mathcal{R}_s = \prod_{i=1}^{m} \mathcal{R}_i = \prod_{i=1}^{m} [1-(1-r_i)^{c_i}] \geq \mathcal{R}_T.$$

4. Solving the optimal R.A problem by using Cukoo algorithm.

The cuckoo is an optimization algorithm developed by Xin-she Yang and Suash Deb in 2009, [22]. The idea was explored by forced brood parasitism of some types of birds (cuckoo) by laying their eggs in the nests of other birds different from them. It leads to a direct conflict with the intruder cuckoo bird. In the event that the bird knows that these exotic eggs belong to the cuckoo bird, it will throw them from the nest or build a new nest. A species of cuckoo (Tapera) in which the female parasitic cuckoo mimics the colors and patterns of eggs of a few select host species. In this way, the reproductive behavior of this type of bird became ideal, as researchers through this pattern were able to apply it in solving various improvement problems [21]. This algorithm was applied to the optimization problem dealt with in this paper, which is the problem of allocating reliability to a waste treatment system to reduce as little as possible while ensuring that the system works for a certain period of time.

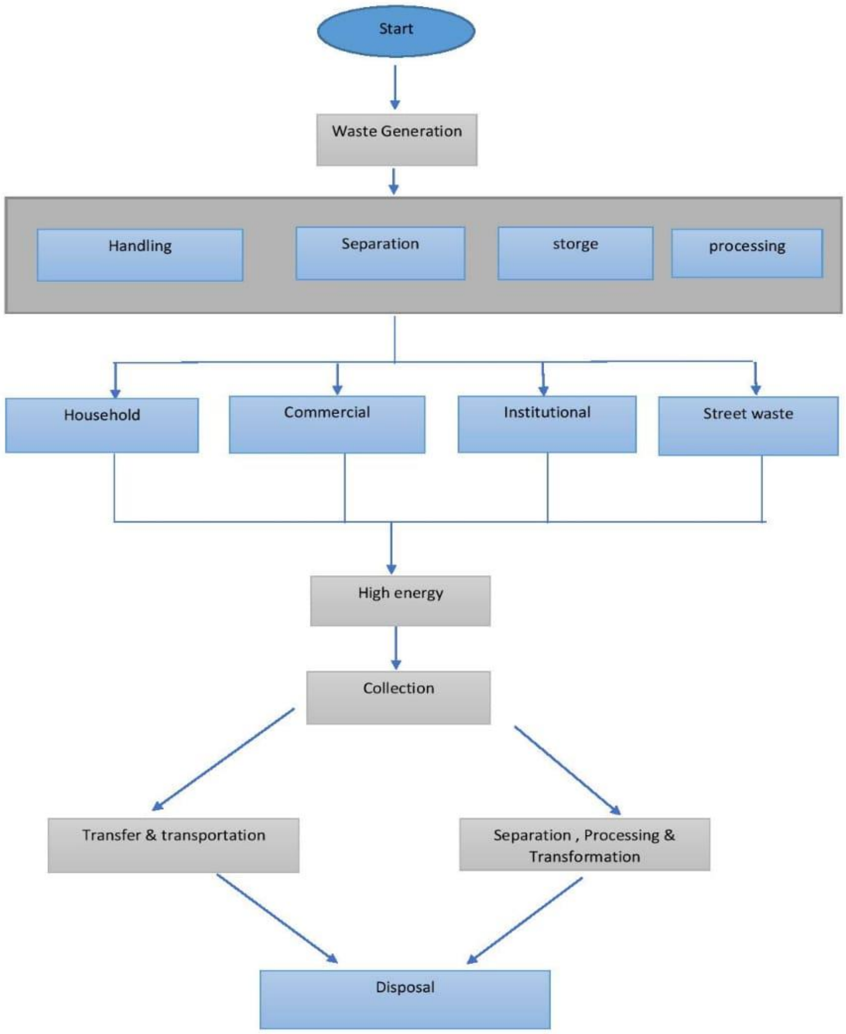

Fig.5: Cuckoo algorithm for waste treatment system.

5. Applications of system waste treatment plant

The problem of optimization with respect to (WPT) as shown in the eq.(1). The problem can be reformulated after entering reliability system of (WPT), where the problem will be as follows

$$\min_{r} \sum_{i=1}^{m} k_i[1-(1-r_i)^{x_i}]^{c_i}$$

Subject to

$$r_1.r_2.r_5.r_6 + r_1.r_2.r_4.r_6 - r_1.r_2.r_4.r_5.r_6 + r_1.r_2.r_3.r_6 - r_1.r_2.r_3.r_5.r_6 - r_1.r_2.r_3.r_4.r_6 + r_1.r_2.r_3.r_4.r_5.r_6. \geq \mathcal{R}_T,$$

after solving the optimization problem using the cuckoo algorithm, results was obtained that can be shown in the following table 1, noting that all units were considered to have the same reliability.

Table 1. Table of optimal R.A for (WTP)

Component	R.A	R. I
1	0.991	0.972
2	0.984	0.982
3	0.932	0.0062
4	0.920	0.0702
5	0.919	0.00526
6	0.992	0.9752

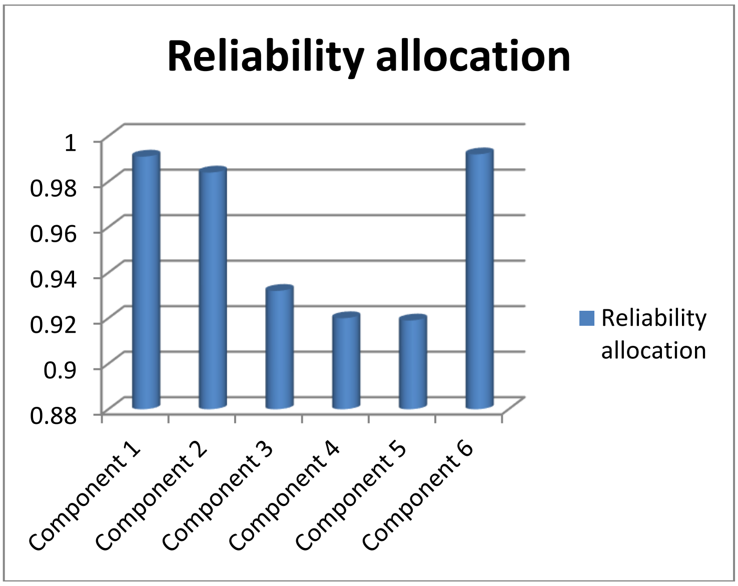

Fig.6. R.A for the (WTP).

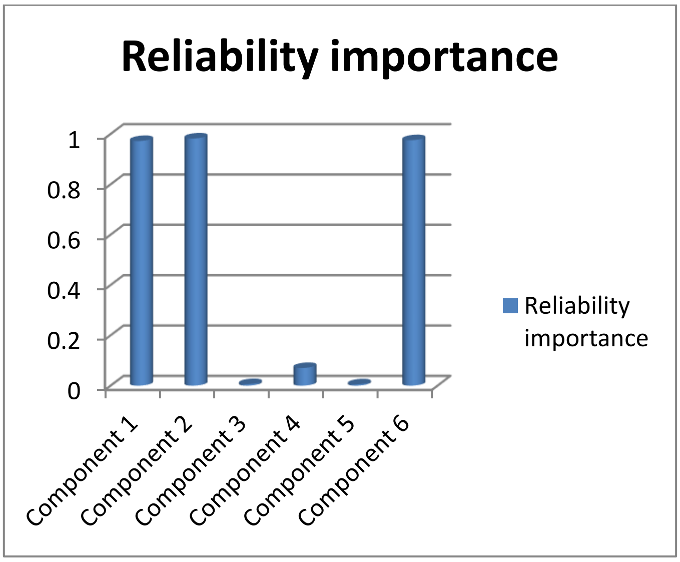

Fig.7. Reliability importance for the (WTP).

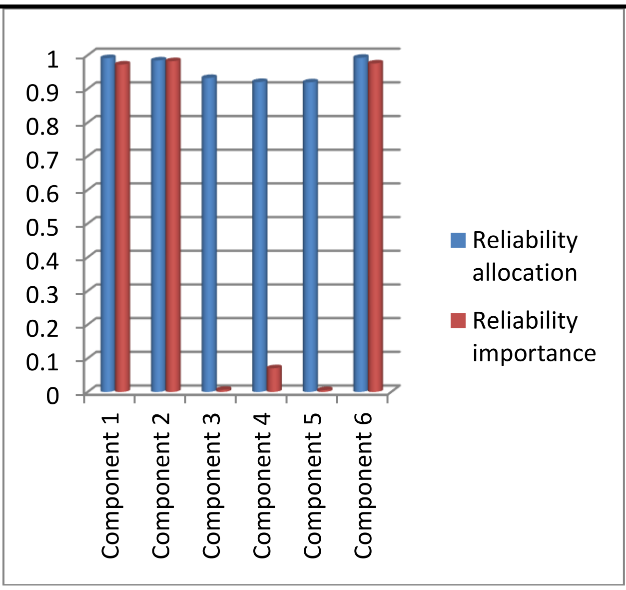

Fig.6. R.A and importance for the (WTP).

6. Conclusion and Discussion

In our research, a solid waste treatment system was used and the reliability of this system was found using the method of (path tracing). The system reliability function was applied within a non-linear programming problem as it is one of the constraints of an optimization problem. As for the C.F, it also depends on reliability (as an objective function of the optimization problem. The reliability problem was solved using (C.A), as the algorithm proved to be very effective in finding the solution in the fastest time and with high accuracy compared to other algorithms. This paper will help many researchers to solve the system problem using other algorithms or methods in the future, and better results can be reached.

References

1. Abed, S. A., Udriste, C. and Tevy, I., Optimal R.A for redundancy series-parallel systems, European Journal of Pure and Applied Mathematics, 10(4), 877-889, (2017).
2. Abed, S. A., (2017). Optimization Techniques and Methods in R.A. (Doctoral dissertation, PhD thesis, University politehnica of Bucharest).
3. Abed, S. A., Sulaiman, H. K., & Hassan, Z. A. H. (2019, September). R.A and Optimization for (ROSS) of a Spacecraft by using Genetic Algorithm. In *Journal of Physics: Conference Series* (Vol. 1294, No. 3, p. 032034). IOP Publishing.
4. Aggarwal, K.K., Reliability engineering,Center for Excellemce in Reliability engineering, Regional engineering College ,Kurukshetra, India,(1993) .
5. Dohmen, K., Inclusion-exclusion and network reliability, The Electronic Journal of Combinatorics, Research Paper R36, 1 - 8, 5 (1998).
6. Ghiani G, Laganà D, Manni E, Musmanno R, Vigo D. Operations research in solid waste management: a survey of strategic and tactical issues. Comput Oper Res. 2014;44:22–32.
7. Hassan, Z. A. H. and Shiker, M. A. K, Using of Generalized Bayes' Theorem to Evaluate the Reliability of Aircraft Systems, Journal of Engineering and Applied Sciences, approved for publication, 2019.
8. Hassan, Z. A. H.and Mutar, E. K., Evaluation the reliability of a high-pressure oxygen supply system for a spacecraft by using GPD method, Al-Mustansiriyah Journal of college of education, vol. special issue . pp. 993 -1004, 2 (2017).

9. Hassan, Z. A. H.and Mutar, E. K., Geometry of reliability models of electrical system used inside spacecraft, 2017 Second Al-Sadiq International Conference on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA), pp. 301-306, (2017).
10. Hassan, Z. A. H.,Udriste, C.and Balan, V., Geometric properties of reliability polynomials, U.P.B. Sci. Bull., vol. 78, no. 1, pp. 3-12, 2016.
11. Hassan, Z. A. H.and Balan, V., Fuzzy T-map estimates of complex circuit reliability, International
12. Conference on Current Research in Computer Science and Information Technology (ICCIT-2017), IEEE, Special issue, pp.136-139, 2017.
13. Kuo,W. ,Prasad, V. R., An annotated overview of system-reliability optimization, IEEE Transactions on Reliability, 176 - 187, 49 (2000).
14. Lakey,P. B., Neufelder, A. M. , System and Software Reliability Assurance Notebook, Rome Laboratory, Rome NY, 6.1 - 6.24, (1996).
15. Mettas, A., R.A and optimization for complex systems, Proceedings Annual Reliability and Maintainability Symposium, Los Angeles, CA, 216-221, January (2000).
16. Mutar, E. K.and Hassan, Z. A. H.,On the Geometry of the Reliability Polynomials,Thesis,University of Babylon, (2017).
17. Powell JC. The evaluation of waste management options. Waste Manag Res. 1996;14(6):515–26.
18. Sharholy M, Ahmad K, Gauhar M, Trivedi RC. Municipal solid waste management in Indian cities – a review. Waste Manag. 2014;34:542–52.
19. Udriste, C., Abed, S. A. and Tevy, I. Geometric programming approaches of R.A. UPB Sci. Bull, 79(3), 3-10, (2017).
20. Udriste, C., Tevy, I., & Abed, S. A. (2017). Problems on multivariate reliability polynomial. *Atti della Accademia Peloritana dei Pericolanti-Classe di Scienze Fisiche, Matematiche e Naturali*, *95*(2), 7.
21. Yu H, Solvang WD, Li S. Optimization of long-term performance of municipal solid waste management system: a bi-objective mathematical model. Int J Energy Environ. 2015;6(2):153–64.
22. Xi BD, Su J, Huang GH, Qin XS, Jiang YH, Huo SL, Ji DF, Yao B. An integrated optimization approach and multi-criteria decision analysis for supporting the waste-management system of the City of Beijing, China. Eng Appl Artif Intel. 2010;23:620–31.
23. X.-S. Yang; S. Deb (December 2009). *Cuckoo search via Lévy flights*. World Congress on Nature & Biologically Inspired Computing (NaBIC 2009). IEEE Publications. pp. 210–214. arXiv:1003.1594v1
24. Zhao, J.; Liu, S.; Zhou, M.; Guo, X.; Qi, L. (July 2018). "Modified cuckoo search algorithm to solve economic power dispatch optimization problems". *IEEE/CAA Journal of Automatica Sinica*. **5** (4): 794–806. doi:10.1109/JAS.2018.7511138. ISSN 2329-9274. S2CID 46935795.
25. [24] Abed, S. A., Aljanabi, M., Ameer, N. H. A., Ismail, M. A., Kasim, S., Hassan, R., & Sutikno, T. (2021). Application of the Jaya algorithm to solve the optimal reliability allocation for reduction oxygen supply system of a spacecraft. Indonesian Journal of Electrical Engineering and Computer Science, 24(2), 1202-1211.