Nanar Journal for Humanities and Social Sciences
University of Hilla
ISSN: 3007-1402; E-ISSN: 3007-1410
DOI Prefix: 10.64002

Importance-Based Reliability Allocation Using a Minimum-Effort Improvement Strategy for Complex Networks

Iktifa Diaa Jaleel

[1] Ministry of Education, Open Education College, Babylon Center, Babylon, Iraq.

*Corresponding author: IKTIFA@gmail.com

Received date: 2025/07/16 **Accepted date: 2025/12/31** **Published date: 2026/03/31**

Abstract

This study explains how to apply a minimum-effort improvement technique to provide reliability to intricate networks based on their importance. The study focuses on how crucial reliability is for identifying key components and determining the best way to distribute reliability throughout a system. We consider a sophisticated network with 10 components, and assume that all components are equally reliable at the start. First, the reliability of each part is calculated, and then the parts are sorted into groups based on their importance. The proposed method makes the system more reliable by equalizing the relevance of parts at different levels and adjusting their dependability values to match. Several instances of enhancement are examined to identify potential remedies within the reliability interval. The results show that improving some elements based on their actual importance does make the whole system work better. The final step in improving things is to adjust the reliability values for the four essential sections. This boosts the system's reliability from 0.6055 to 0.94. The recommended heuristic method is a simple yet effective strategy to make systems more reliable and spread reliability across complex networks.

Keywords:

Reliability importance, reliability allocation, complex networks, system reliability improvement, heuristic optimizat

https://doi.org/10.64002/x3xvst73

1. Introduction

Reliability theory refers to a system's capacity to fulfill its designated task within a predetermined timeframe [1-13]. This enhances system performance and diminishes the likelihood of failure, applicable to aircraft, engines, and various products. As the proliferation of intricate devices and systems arises from development, the potential for operational failures escalates, making complex networks increasingly significant across diverse domains, including engineering, biology, and other scientific fields. Schematics can be utilized in network science and systems modeling to diminish the likelihood of failure [2, 4]. The significance of each unit inside the system must be understood and quantified. What is the level of each unit within the system? Assess the significance of dependability as the fundamental factor in system failure. Where component malfunction coincides with system malfunction, Link significance to personalization. The objective of customization is to employ the reliability model for subsystem allocation. The values for systems are established as trusted parameters to attain customized dependability, hence enhancing overall system reliability [5, 10].

2. Some basic definitions and concepts

Discuss some of the basic concepts that need in studying this research, and among these concepts is the importance of reliability and allocation.

2.1 Reliability Importance

The probability that a component will be crucial to a system failure that is, that the failure of the component will occur simultaneously with the collapse of the system defines the relevance of a component. In terms of math, it can be written as [3, 11]:

$$I_i = \frac{\partial R_s}{\partial R_i} \qquad (1)$$

2.2. Reliability Allocation

The process by which the failure of a system is determined by using a logical method through the systems of the sub-system and its components. We define the system reliability objective of the individual components within the system that ensure access to the overall goal of system reliability. For each for matting we use the component to refer to a typical unit or sub- system, which can be formulated in the allocation of reliability.

https://doi.org/10.64002/x3xvst73

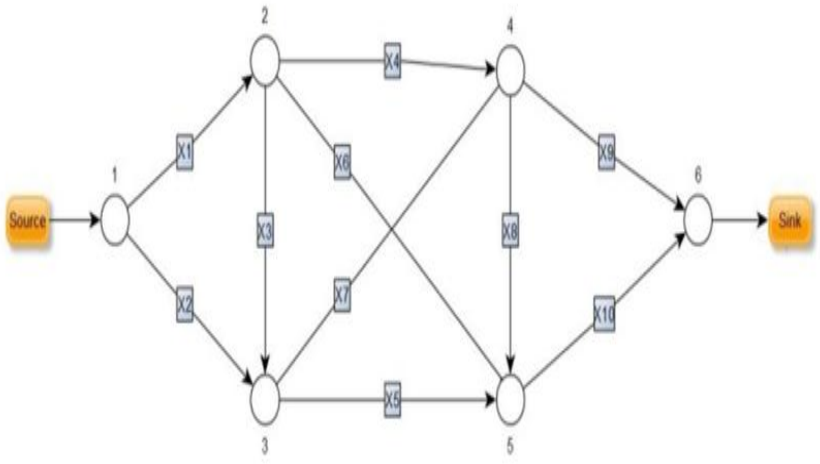

Fig. 1. Complex Network

The reliability function was calculated from the minimum paths of the system by using MATLAB where contains (122) terms [12, 13].

$R_s = R_1R_4R_9 + R_1R_6R_{10} + R_2R_5R_{10} + \cdots\cdots + 2R_1R_3R_4R_5R_6R_7R_8R_9R_{10}$ (2)

3. Calculation the reliability importance

The reliability of a network with m components is important. The impact of the i-th component on the network's overall reliability is indicated by its index (I_i). In order to increase network reliability, designers must have this information, since they will prioritize enhancing the dependability of components that have the biggest effects on network reliability. However, in intricate networks, this becomes a challenging task. The reliability importance of the i-th component has a value between zero and one, which is determined by R_i and the component's location within the network [8, 12]. This value depends on Ri and the position of i-th component in network.

4. Using importance to calculate the allocation

In this section, equate the importance of components that are at different levels of importance, and thus vehicles will increase their reliability. Therefore, we will try to get the best allocation by equating the importance of components that are at different levels. Thus, find the relationship between allocation and the importance of reliability. To illustrate this, we take the following example. Illustrative example: Consider a complex network as shown in figure (1), where Rs equal to (0.6055) in order to increase it to (0.94). Calculated the importance of equal reliability for each component in table (1).

Table 1. Values of R_i and I_i

Components (R_i)	Value	Importance (I_i)	Levels
R_1, R_{10}	0.60	0.3635	1
R_2, R_9	0.60	0.2919	2

https://doi.org/10.64002/x3xvst73

R_7	0.60	0.1595	3
R_4, R_5	0.60	0.1167	4
R_6	0.60	0.0705	5
R_3, R_8	0.60	0.0336	6

Case (1): Equating the first level with the second level

choose the component R_1 from the first level of the importance which consider more important and the component R_2 from the second level which consider less important and equal the importance of reliability to them and, Substituted the reliability values for each component except for components R_1 and R_2 in the reliability function of the system.

$$\frac{\partial R_s}{\partial R_1} = \frac{\partial R_s}{\partial R_2}$$

$$0.717\text{-}0.589\ R_2 = 0.666\text{-}0.589\ R_1 \quad (3)$$

$$0.717R_1 + 0.666\ R_2 - 0.589\ R_1 R_2 = 0.76 \quad (4)$$

By solving two equations (3) and (4), we get:

$R_1 = 0.878$, $R_2 = 0.999$

These values belong to the interval [0,1] and satisfy the objective.

Case (2): Equating the second level with the third level

Choose the component R2 from the second level of the importance and the component R7 from the third level and equal the importance of reliability to them, them, Substituted the reliability values for each component except for components R2 and R7 in the reliability function of the system.

$$\frac{\partial R_s}{\partial R_2} = \frac{\partial R_s}{\partial R_7}$$

$$0.179\ R_2 + 0.025 = 0\ .179\ R_7 + 0.179 \quad (5)$$

$$0.179\ R_2 + 0.487\ R_7 + 0.179\ R_2 R_7 + 0.787 = 0.76 \quad (6)$$

After solving the two equations simultaneously, the results are:

$R_2 = -3.5057$, $R_7 = -4.3629$

The results were outside the range of the period and did not achieve the goal.

Case3: Equating the third level with the fourth level

Also, can be choose R7 from third level and R4 from fourth level and equal the importance of reliability to them:

$$\frac{\partial R_s}{\partial R_7} = \frac{\partial R_s}{\partial R_4} \quad (7)$$

Case4: Equating the fourth level with the fifth level

Choose R4 from fourth level and R6 from fifth level and equal the importance of reliability to them:

$$\frac{\partial R_s}{\partial R_4} = \frac{\partial R_s}{\partial R_6} \quad (8)$$

Case5: Equating the first level with the sixth level

Choose R_1 from fourth level and R3 from fifth level and equal the importance of reliability to them:

$$\frac{\partial R_s}{\partial R_1} = \frac{\partial R_s}{\partial R_3} \quad (9)$$

https://doi.org/10.64002/x3xvst73

In the same way, for cases 3, 4, and 5, the values were outside the interval and did not achieve the goal.

Table 2. Values of R_i and I_i after first improvement.

Components (R_i)	Value	Importance (I_i)	Levels
R_{10}	0.60	0.4416	1
R_9	0.60	0.3638	2
R_7	0.60	0.16	3
R_1, R_2	0.878,0.99	0.128	4
R_4, R_5	0.60	0.1125	5
R_6	0.60	0.0663	6
R_3, R_8	0.60	0.0001	7

Case 6: Equality of the first level with the second level in all their components

In this case, which is more general than the previous cases, we equated two components from the first level (R_1, R_{10}) with two components from the second level (R_2, R_9)

$$\frac{\partial R_s}{\partial R_1} = \frac{\partial R_s}{\partial R_2}$$
$$\frac{\partial R_s}{\partial R_9} = \frac{\partial R_s}{\partial R_{10}} \qquad (10)$$

$0.717-0.589\ R_2= 0.666-0.589\ R_1=0.717-0.589\ R_9=0.666-0.589\ R_{10}= 0.13$ (11)

After solving the equation, the results were

$R_1=0.90$, $R_2=0.99$, $R_{10}=0.90$, $R_9=0.9$.

This increased the reliability of the system (R_s) to 0.94.

Table 3. Values of R_i and I_i after second improvement.

Components (R_i)	Value	Importance (I_i)	Levels
R_1, R_{10} R_2, R_9	0.90 0.99	0.13	1
R_7	0.60	0.13	1
R_4, R_5	0.60	0.089	2
R_6	0.60	0.053	3
R_3, R_8	0.60	0.0001	4

From viewing the values in table (3) we record the following observation:

1.There are four components whose reliability equal and greater than 0.90, which R_1 R_2, R_9 and R_{10}.

2.The importance of reliability is equal for the four components R_1 R_2, R_9 and R_{10}.

3.The importance of seventh component has increased through improvement.

https://doi.org/10.64002/x3xvst73

4. These results after the second improvement are considered the best results.
5.the best value of system reliability R_S=0.94, this is an excellent improvement.

5. Conclusion

This study suggested an importance-based approach to enhance system reliability in intricate networks via reliability allocation. We first figured out how important each part's reliability was by assuming that all parts had the same reliability value. Based on these values, the parts were assigned to different levels of importance. The proposed method then used an important equalization mechanism across components at different levels to determine the optimal allocation of reliability.

We looked at several ways to improve things. The findings indicated that enhancing individual components across varying levels of importance does not consistently yield viable solutions within the reliability interval. But when improvements were made to parts that were both at the first and second significance levels simultaneously, a workable and useful allocation was achieved. In this example, four important parts became more reliable, which made the whole system much more reliable.

In the first stage of improvement, the system's reliability went from 0.6055 to 0.76. In the second step, it reached 0.94. These results show that the suggested heuristic strategy is an effective way to find important parts and assign dependability with little effort. The method can be used across different types of engineering systems and complex networks, where it is necessary to make the system more reliable while keeping the number of parts that need to be changed to a minimum.

References

[1] Mettas, A., Reliability allocation and optimization for complex systems, Proceedings

[2] Annual Reliability and Maintainability Symposium, Los Angeles, CA, January (2000), pp. 216-221.

[3] Srinath, L. S., Concepts in Reliability Engineering, East-West Press Private Ltd., (1985).

[4] Fadhil, R. A., & Hassan, Z. A. H. Simple method to extract minimal cut sets of a direct network. Journal of Interdisciplinary Mathematics, 26(5), 903-908. (2023).

[5] Kuo S. Y & J. Zuo Ming, Optimal reliability modeling: principles and applications. John Wiley, Sons, (2003).

[6] Abdullah, G., & Hassan, Z. A. H.. Using of Genetic Algorithm to Evaluate Reliability Allocation and Optimization of Complex Network. In IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 4, p. 042033). IOP Publishing. (2020, November).

[7] Ireson W. G., Ireson, C. R. Coombs, and Moss, R. Y., Handbook of Reliability Engineering and Management, 2nd ed., McGraw-Hill Comp., U.S.A., (1995).

[8] Hassan, Z. A. H., & Muter, E. K.. Geometry of reliability models of electrical system used inside spacecraft. In 2017 Second Al-Sadiq International Conference on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA) (pp. 301-306). IEEE. (2017, December).

https://doi.org/10.64002/x3xvst73

[9] Nicolae J. & C. Costin. Methods for analyzing the reliability of electrical systems used inside aircrafts. Recent Advances in Aircraft Technology. Intech open, (2012).
[10] Hassan Z. A. H., Udriste C. and Balan V. Geometric properties of reliability polynomials U.P.B. Sci. Bull. 78 3-12. (2016).
[11] Dhillon, B. S., Design Reliability Fundamentals and Applications, 1st ed., CRC Press, Taylor, Francis group, Boca Ration, Florida, (1999).
[12] Ansell J. I. & Phillips, M. J., Practical Methods for Reliability Data Analysis, Oxford University Press, New York, (1994).
[13] Abraham, J. A., An improved algorithm for network reliability. IEEE Transactions on Reliability, April (1979), R-28: pp. 58-61.

https://doi.org/10.64002/x3xvst73