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EMPLOY ANT COLONY ALGORITHM TO SOLVE RELIABILITY OPTIMIZATION PROBLEM FOR AN COMPLEX NETWORK

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Abstract

In this article, the reliability of a complex network has been calculated as a complex system using limited paths. The reliability of this system has been assigned to explore alternate ways assignment of reliability values on reducing the total expense of the process. Among the initial findings were:

(i) To quantify Comprehensive device costs, three cost functions were used: The paradigm of exponential behavior, the exponential behavior model and finally, there's the logarithm model.

(ii) Solving the challenges of maximizing the dynamic system's reliability, the reliability of each part of the system was determined using the ant colony optimization (ACO) algorithm.

Keywords: Reliability allocation, Reliability optimization, the Ant colony algorithm.

1. Introduction

In the present article, we watched the installed complex system's efficiency. By using limited paths across relation matrices, this system was found to be efficient. (To create minimum paths, remove nodes) as well as Boolean algebra [1-3]. The goal of evaluating to be learn about the protection of the sophisticated unit that has been built. Despite the networks' foundations, the optimum distribution dependability is treated as a mathematical task in this research [2, 4-7]. Each and every dynamic component Each device offers a unique set of features. dependability standards that are optimized and reliant on its importance. The goal is to improve device reliability while lowering total expenses. In order to achieve the highest level of efficiency in general, depending on the position of each element in the System, which varies between the component and the component, such components may require large allocations[6, 8]. Engineers working on improving mechanical and electrical systems encounter a variety of challenges. The focus of this work is on complicated structure allocation and improvement, in addition to the cost system , which can be assessed In terms of size , and proportion, or other criteria[8-10]. The dependability of this component is based on two key needs. To begin, the model should be used to determine the input variable reliability. You will change the parameters of the suggested cost parameter. Engineers may now upgrade their duties for each machine and prepare for the utmost Each device's productivity, second, the model's analytical performance should be balanced of the input system. This can be a huge difficulty in simple structures, but it can be In complex systems, this is a significant issue [7, 11]. The expenses are calculated using the ant colony optimization algorithm, which uses complex systems to solve optimization problems[12-15]. The algorithm uses three cost functions " Modeling activity exponentially with the viability factor, The exponential behavior paradigm and a logarithmic model".

2. Optimization of complex system

Consider a system of interconnected components. [1-3, 16]. We are reliant on statements.: $0 \leq R_i \leq 1$ dependability of a component i ; $C_i(R_i)$ the Individual Costs, Components i , $C(R_1,\ldots,R_n) = \sum_{i=1}^{n} a_i c_i (Ri)$ Parts' Prices $a_i > 0$; The effectiveness of the system is measured in R_s , the device's reliability objective is denoted by the letter RG. Each component of the scheme has a distinct goal, and there are several options. Device modules have their own set of features. varying levels of assurance in the same characteristics. The objective is to ensure that any or all gadget components are trustworthy. The Q issue is a non-linear threshold with an evaluable cost and function [15-20]. Seek out

$$\text{Minimize} C(R_i, \ldots, R_n) = \sum_{i=1}^{n} a_i C_i(R_i), \quad a_i > 0, \tag{1}$$

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within the terms of

$$R_G \leq R_S$$

$$0 \leq R_i \leq 1, \text{ such } \quad i = 1, \dots, n.$$

Let's pretend the cost function is appropriate.. $C_i(R_i)$ satisfies those requirements [12]. The favorable, unique role is being improved.
$\left[\Rightarrow \frac{dC_i}{dR_i} \geq 0\right]$.
The goal of the prior strategy was to achieve a cost basis that included everything [2, 4]. The stability limit of the system has been lowered. However It's in the vicinity the scope of R_G.

3. Application to complex network

All components in the complex network illustrated have the same as in fig. (1) primary trust level of 90% at the specified periods [19, 21-24]. The system's aim for stability is 90 percent at any given time. The dependability polynomial for the proposed technique was found using the approach to minimal path [14, 25].

$R_S = R_1R_9 R_{10} + R_2 R_8 R_{10} + R_2 R_5 R_7 R_{10} + R_3 R_4 R_7 R_{10} + R_1 R_6 R_8 R_{10} + R_2 R_6 R_9 R_{10}$
$- R_1 R_2 R_6$
$R_8 R_{10} - R_1 R_2 R_6 R_9 R_{10} + R_1 R_5 R_6 R_7 R_{10} - R_1 R_2 R_8 R_9 R_{10} + R_3 R_4 R_5 R_8 R_{10} - R_2 R_5$
$R_7 R_8$
$R_{10} - R_1 R_6 R_8 R_9 R_{10} - R_2 R_6 R_8 R_9 R_{10} - R_1 R_2 R_5 R_6 R_7 R_{10} - R_2 R_3 R_4 R_5 R_7 R_{10} - R_2 R_3$
R_4
$R_5 R_8 R_{10} - R_1 R_2 R_5 R_7 R_9 R_{10} - R_1 R_3 R_4 R_7 R_9 R_{10} - R_2 R_3 R_4 R_7 R_8 R_{10} + 2R_1 R_2 R_6$
$R_8 R_9$
$R_{10} -R_1 R_5 R_6 R_7 R_8 R_{10} + R_3 R_4 R_5 R_6 R_9 R_{10} - R_3 R_4 R_5 R_7 R_8 R_{10} - R_1 R_5 R_6 R_7 R_9 R_{10} -$
$R_2 R_5 R_6 R_7 R_9 R_{10} - R_1 R_3 R_4 R_5 R_6 R_7 R_{10} - R_1 R_3 R_4 R_5 R_6 R_8 R_{10} - R_1 R_3 R_4 R_5 R_6 R_9$
$R_{10} +$
$R_1 R_2 R_5 R_6 R_7 R_8 R_{10} - R_1 R_3 R_4 R_6 R_7 R_8 R_{10} - R_2 R_3 R_4 R_5 R_6 R_9 R_{10} + 2R_2 R_3 R_4 R_5R_7$
R_8
$R_{10} + 2R_1 R_2 R_5 R_6R_7 R_9 R_{10} - R_1 R_3 R_4 R_5 R_8 R_9 R_{10} - R_2 R_3 R_4 R_6 R_7 R_9 R_{10} + R_1 R_2$
$R_5 R_7$

$R_8\ R_9\ R_{10}$ - $R_3\ R_4\ R_5\ R_6\ R_7\ R_9\ R_{10}$ - $R_3\ R_4\ R_5\ R_6\ R_8\ R_9\ R_{10}$ + $R_1\ R_5\ R_6\ R_7\ R_8\ R_9\ R_{10}$ + R_2
R_5
$R_6R_7\ R_8\ R_9\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_8\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_5$
R_6
R_9R_{10} + $R_1\ R_2\ R_3\ R_4\ R_5\ R_7\ R_9\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_6\ R_7\ R_8\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_5\ R_8\ R_9$
R_{10} +
$R_1\ R_2\ R_3\ R_4\ R_6\ R_7\ R_9\ R_{10}$ + $R_1\ R_2\ R_3\ R_4\ R_7\ R_8\ R_9\ R_{10}$ + 2 $R_1\ R_3\ R_4\ R_5\ R_6\ R_7\ R_8\ R_{10}$ +
2 $R_1\ R_3\ R_4\ R_5\ R_6\ R_7\ R_9\ R_{10}$ + 2 $R_1\ R_3\ R_4\ R_5\ R_6\ R_8\ R_9\ R_{10}$ + 2 $R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_9\ R_{10}$ +
$R_1\ R_3\ R_4\ R_5\ R_7\ R_8\ R_9\ R_{10}$ + $R_2\ R_3\ R_4\ R_5\ R_6\ R_8\ R_9\ R_{10}$ – 2 $R_1\ R_2\ R_5\ R_6\ R_7\ R_8\ R_9\ R_{10}$ +
$R_1\ R_3\ R_4\ R_6\ R_7\ R_8\ R_9\ R_{10}$ + $R_2\ R_3\ R_4\ R_6\ R_7\ R_8\ R_9\ R_{10}$ + $R_3\ R_4\ R_5\ R_6\ R_7\ R_8\ R_9\ R_{10}$ –
2 $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_8\ R_{10}$ – 3 $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_9\ R_{10}$ – 2 $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_8$
R_9
R_{10} - 2 $R_1\ R_2\ R_3\ R_4\ R_5\ R_7\ R_8\ R_9\ R_{10}$ – 2 $R_1\ R_2\ R_3\ R_4\ R_6\ R_7\ R_8\ R_9\ R_{10}$ – 3 $R_1\ R_3\ R_4\ R_5\ R_6$
$R_7\ R_8$
$R_9\ R_{10}$ -2 $R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_8\ R_9\ R_{10}$ + 4 $R_1\ R_2\ R_3\ R_4\ R_5\ R_6\ R_7\ R_8\ R_9\ R_{10}$

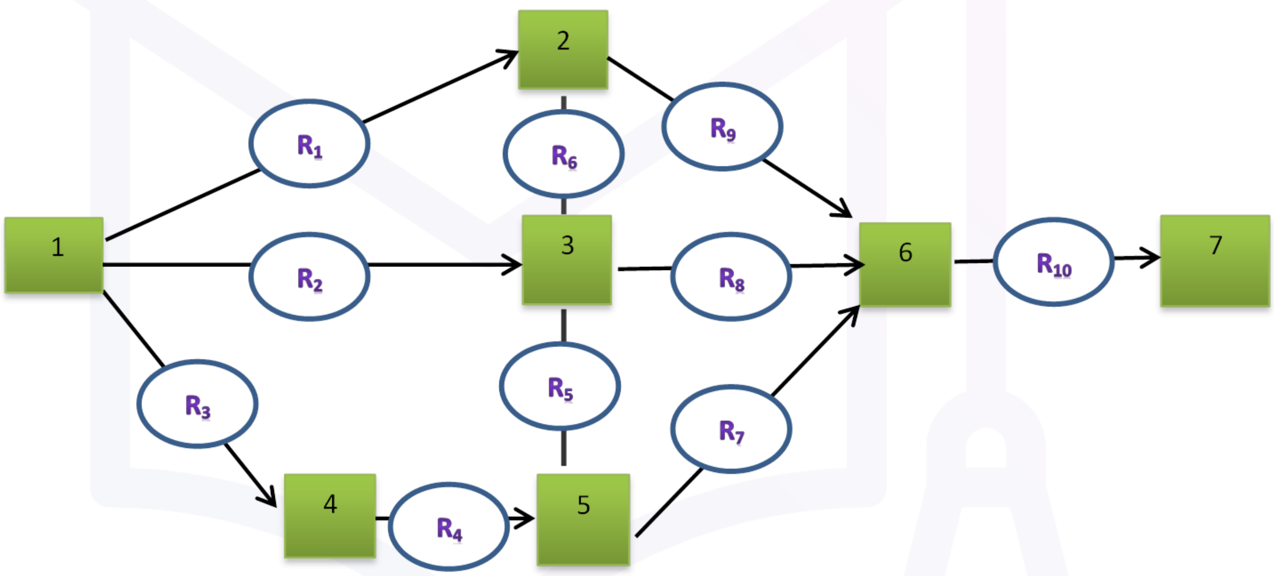

Figure 1 : Complex Network.

4. Three cost models for reliability

4.1 Model of exponential behavior with a feasibility parameter

Suppose $0 < f_i < 1$ be the feasibility factor, $R_{i,min}$ be minimum reliability and $R_{i,max}$ be maximum reliability [26-30]]. Exponential behavior is another important cost function.

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$$C_i(R_i) = \exp[(1-f_i)\frac{R_i - R_{i,min}}{R_{i,max} - R_i}], R_{i,min} \le R_i \le R_{i,max}, i = 1,2,3,\dots,n. \quad (4.1)$$

The issue of optimization then:

Minimize $C(R_i,\dots,R_n) = \sum_{i=1}^{n} a_i \exp[(1-f_i)\frac{R_i - R_{i,min}}{R_{i,max} - R_i}], i = 1,2,\dots,n.$

Subject to:

$$Rs \ge R_G$$

$$R_{i,min} \le R_i < R_{i,max}, i = 1,\dots,n.$$

Table 1: The Optimal Reliability Allocation (ACO).

Components	R_i	C_i
R_1	0.88761	51.88
R_2	0.88761	51.88
R_3	0.81776	9.4278
R_4	0.87665	34.931
R_5	0.81568	9.1406
R_6	0.61178	2.1988
R_7	0.84618	15.65
R_8	0.75824	4.7977
R_9	0.87665	34.931
R_{10}	0.9133	193.78
R_S	0.90166	204.31

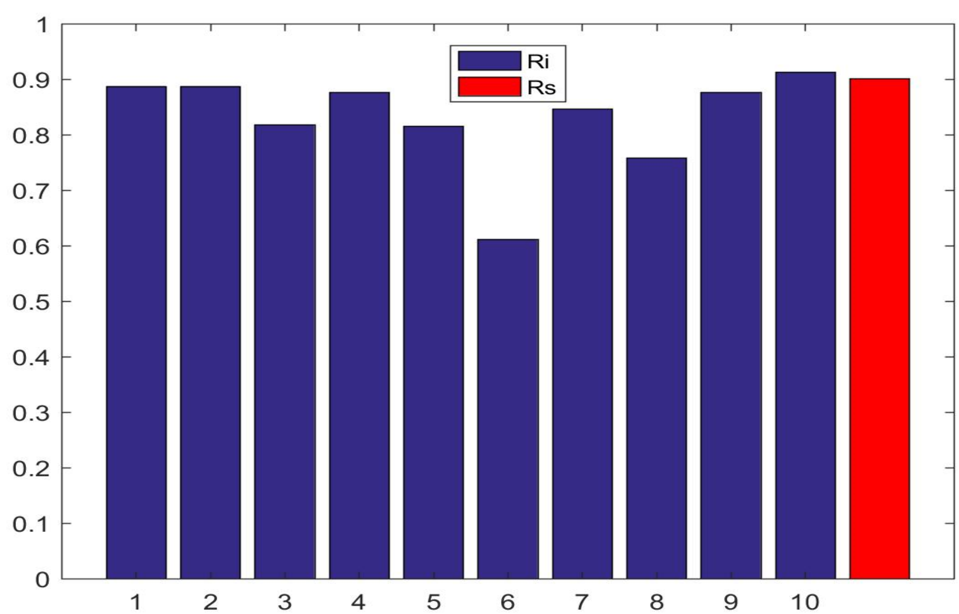

Figure 2: Allocating reliability using exponential behavior model with feasibility factor model for complex network.

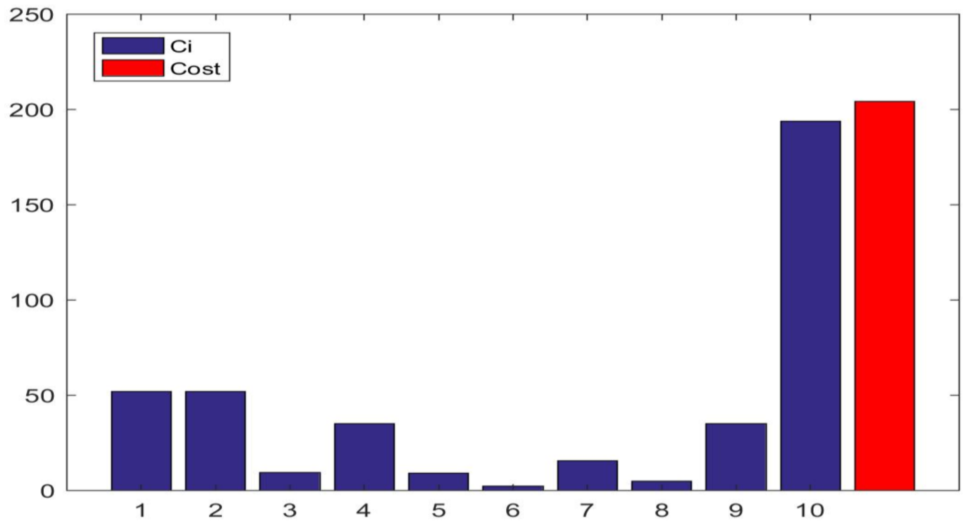

Figure 3 : A cost function for a model-viable exponential behavior process.

4.2 Exponential behavior model

Suppose $0 \le R_i$, and $R_i \le 1$ and, Constants a_i and b_i, where $i = 1, \ldots, n$.. The exponential procedure is the most important cost function. Suggested it in the following format:

$$C_i\,(R_i) = a_i e^{\left(\frac{b_i}{1-R_i}\right)}, a_i > 0, b_i > 0, \quad \text{where} \quad i = 1, \ldots, n. \qquad (4.2)$$

The issue of optimization then:

$$\text{Minimize } C(R_i, \ldots, R_n) = \sum_{i=1}^{n} a_i\, e^{\left(\frac{b_i}{1-R_i}\right)}, \text{ where } i = 1, \ldots, n.$$

Subject to:

$$R_G \le R_S$$

$$0 \le R_i \le 1, \quad \text{where} \quad i = 1, \ldots, n.$$

Table 2: The Optimal Reliability Allocation (ACO).

Components	Ri	Ci
R_1	0.88761	85.535
R_2	0.88761	85.535
R_3	0.81776	15.544
R_4	0.87665	57.591
R_5	0.81568	15.07
R_6	0.61178	3.6253
R_7	0.84618	25.803
R_8	0.75824	7.9101
R_9	0.88761	85.535
R_{10}	0.9133	319.49
R_S	0.90222	350.82

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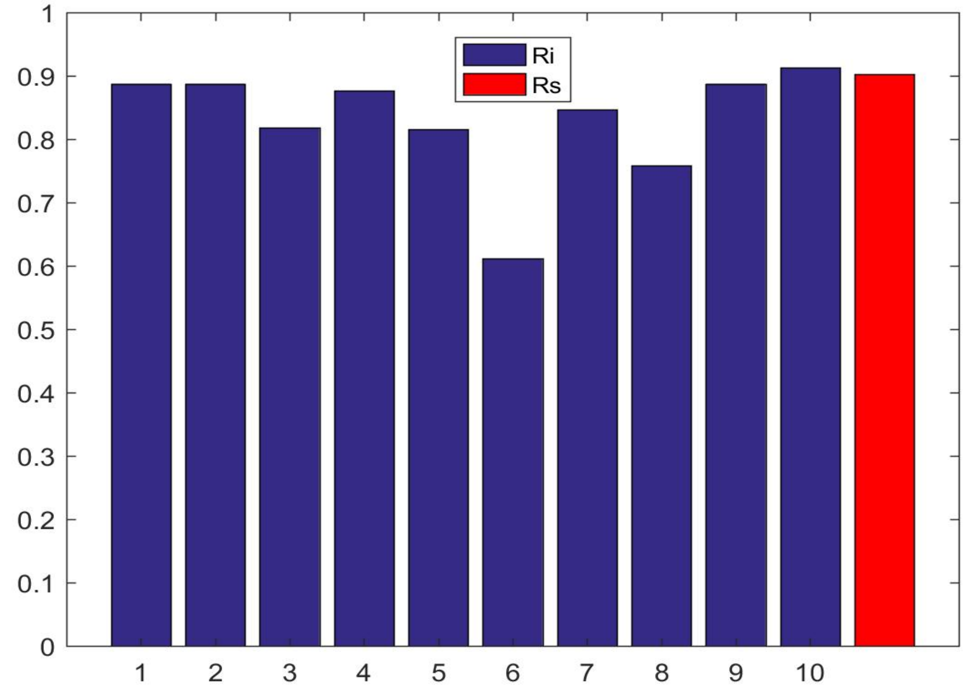

Figure 4: Allocating reliability for complex network by the exponential behavior model..

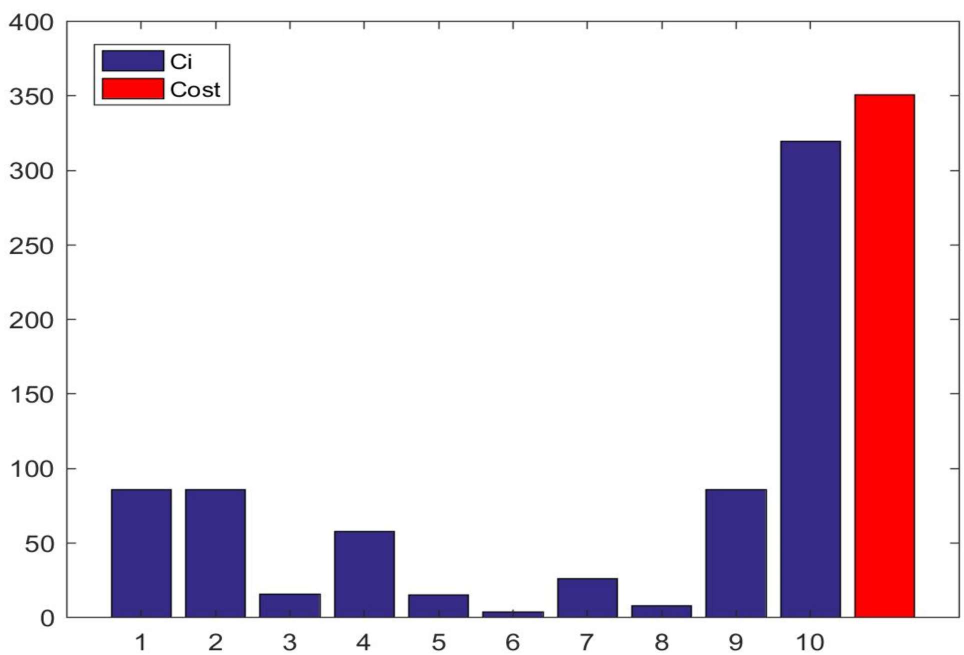

Figure 5: A cost function of a complicated network is determined using the exponential behavior model.

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4.3 Logarithmic model

Let $0 \leq R_i$, and $R_i \leq 1$ and, Constants a_i where $i = 1, \dots, n$. Let's suppose it in the form

$$C_i(R_i) = a_i \ln\left(\frac{1}{1-R_i}\right), a_i > 0 , \; i = 1, \dots, n \tag{4.3}$$

The issue of optimization then.:

$$\text{Minimize} C(R_i, \dots, R_n) = \sum_{i=1}^{n} a_i \ln\left(\frac{1}{1-R_i}\right), \quad \text{where} \quad i = 1, \dots, n.$$

Subject to:

$$R_G \leq R_S$$
$$0 \leq R_i \leq 1, \quad \text{where} \quad i = 1, \dots, n.$$

Table 3: Table for ACO-Based Optimal Reliability Allocation

Components	R_i	C_i
R_1	0.94267	2.8589
R_2	0.994	5.116
R_3	0.54326	0.78364
R_4	0.61	0.94161
R_5	0.56	0.82098
R_6	0.86697	2.0172
R_7	0.738	1.3394
R_8	0.912	2.4304
R_9	0.994	5.116
R_{10}	0.999	6.9078
R_S	0.99818	14.166

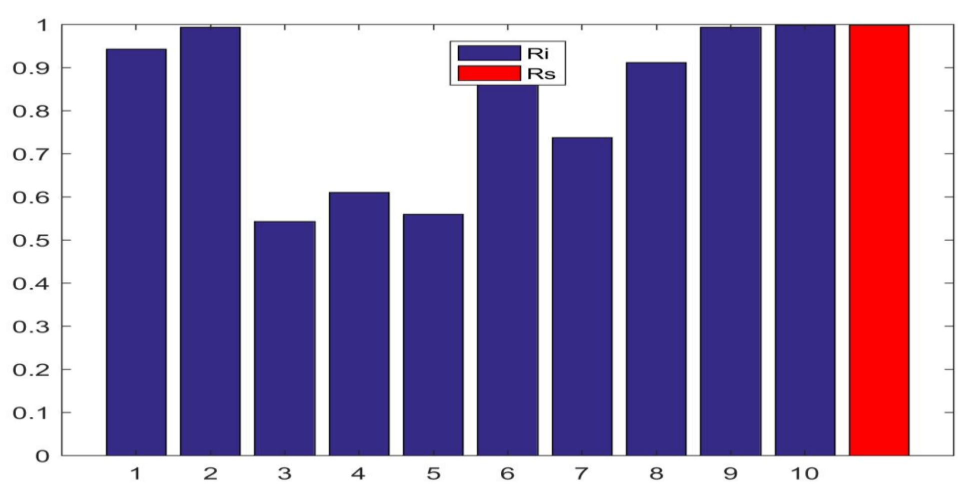

Figure 6: Allocating reliability for complex systems using the logarithmic model

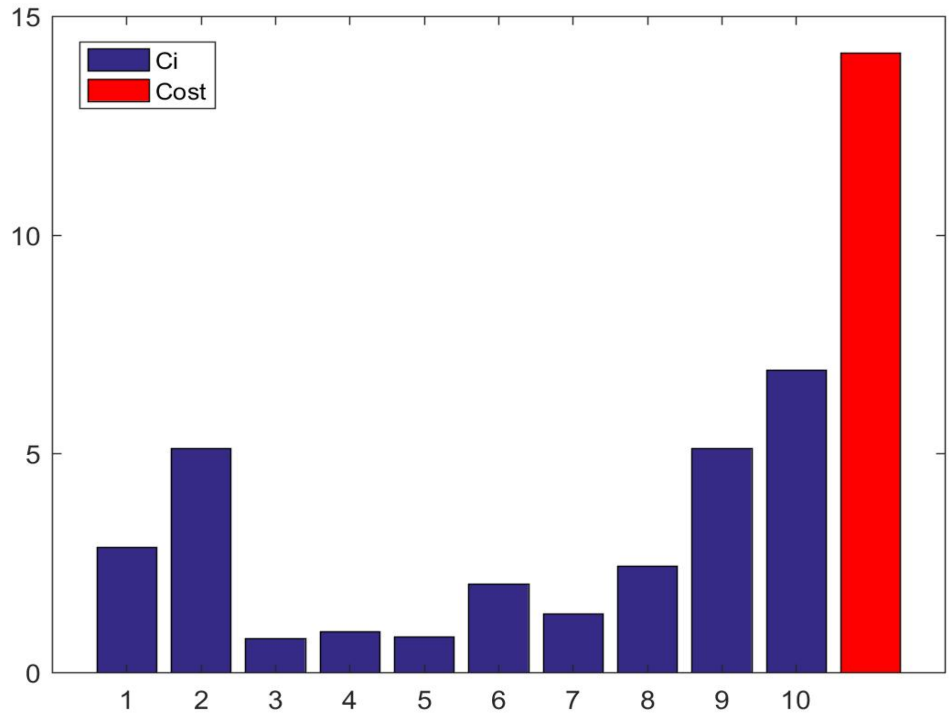

Figure 7: A logarithmic formula is by to calculate a cost function for a complex structur

Table 4 : The Presenting Three Cost Function Models' Solutions to The Reliability Allocation Problem's (ACO)

Components	The first cost function	The second cost function	The third cost function
R_1	0.88761	0.88761	0.94267
R_2	0.88761	0.88761	0.994
R_3	0.81776	0.81776	0.54326
R_4	0.87665	0.87665	0.61
R_5	0.81568	0.81568	0.56
R_6	0.61178	0.61178	0.86697
R_7	0.84618	0.84618	0.738
R_8	0.75824	0.75824	0.912
R_9	0.87665	0.88761	0.994
R_{10}	**0.9133**	**0.9133**	**0.999**
R_S	0.90166	0.90222	0.99818

5. Review the Outcomes

Table 4 shows the three cost functions we employed. and found that the logarithmic model provided the best results, with Rs=0.99818. Despite the fact that the cost of each complicated system component was computed, the overall Each cost function's cost was determined using the (ACO), and a function's value was an exponential behavior model with a feasibility factor of (204.31). While a function's cost with an exponential behavior model is (350.82) and the logarithmic model's last cost of a function (14.166).

6. Conclusion

The challenge of enhancing a complicated network was handled in this article by assigning the dependability of system components according to their significance. For three costs with constraints, the topic was also treated as a nonlinear programming challenge (reliability of complex systems). To deal the reliability allocation problem, the ant colony optimization (ACO) method was utilized. A comparison was made between the findings when the data and discussions When the three cost functions were examined, The Logarithmic model proved to be the more effective than them. Component 10 earned the highest support, according to the reliability allocation issue.. The benefit of this paradigm is that it accepts any algorithm., no matter how complex, to be implemented using mathematical techniques.

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