



An Accurate Allocation of Reliability and Cost Estimation for Architecture-based Software using DRMPA

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Abstract— All traditional system reliability allocation is conducted on the specified reliability requirement alone. The all approaches are not used the reliability requirement together with a CL. In this paper, we will propose a new approach for allocating the reliability and setting the initial level reliabilities to all components of the system with confidence level approach and we proposed Dynamic Risk Management Programming Algorithm(DRMPA) for Reducing the risk cost from the expected cost and finally we compared the Dynamic Programming Algorithm(DA),At the end we proposed the best reliability allocation with maximum and required reliability of the system with minimum development cost is using proposed approach.

Keywords— Software Reliability allocation, Architecture-based software, Risk, Cost, Component Based Software

I. INTRODUCTION

One of the very important and mandatory for reliability activities in Design Of Reliability Allocation (DFRA) is the system reliability allocation at the early stage that is Design stage .It is an important issue for the sum of security applications, design point of view. In general the system reliability is given for the product performance requirement under the normal condition (eg: the probability of failure for 2-year operation should be less than < 0.05 with a confidence level of 90%). A complex system is consists of many sub systems, and all are developed concurrently and sometimes independently. These type of systems too late to validate the system reliability until the final system prototype is ready after months or years of development. From the project management team point of view, the reliability for each subsystem or component of a system or sub-function or sub component should be examined as early as possible. In this connection, allocating a reasonable requirement to each subsystem and sub function based on the system reliability requirement is very important thing. So we can use many reliability allocation approaches, such as AGREE, Weighted, Equal reliability, Cost based methods. All traditional system reliability allocation is conducted on the specified reliability requirement alone. The above all approaches are not used the reliability requirement together with a CL.

II. COMPONENT RELIABILITY ALLOCATION

The development cycle for many systems such as medical devices, military equipment usually is very long .Here the system reliability requirement should be allocated to each subsystem as early as possible in the product development stage. If each subsystem cannot meet its own reliability requirement, then the final system will not be able to meet the requirement. Due to this reason Due to this reason, many reliability allocation methods have been proposed in the past half century [1]. The simplest reliability allocation method is the so called *equal reliability allocation*. This method is used for a system with a serial reliability configuration. For example, assume a system has three independent subsystems A, B, and C.

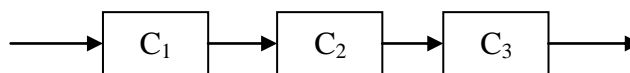


Figure 1 Simple Series Diagram

The system reliability is a function of the subsystem reliability, which is

$$R_S = R_{C1} * R_{C2} * R_{C3} \text{ ----- (1)}$$

Where R_S is the system reliability. If the required reliability R_S is 0.95 the reliability of each system will be

$$R_{C1} = R_{C2} = R_{C3} = (R_S)^{1/3} = 0.9833 \text{ ----- (2)}$$

Required minimum reliability of each subsystem in series connection is 0.9833 and the total requirement of total system reliability is 0.95.

Finally we need to test the each subsystem is meeting the required reliability or not.

For example: 200 samples for subsystem C_1 is tested and the result is obtained in two cases.

In case I: no failure is found means that the system reliability is 1. In case II any failure is happened then the failure ratio must be in the following table .The target system reliability should be minimum of 0.95 clearly given. Each subsystem should be above 0.9833.then the system allows only three failures only. The sample runs of the system and its failures and its reliability of the system is given in the following table 1.

Table I Example For The 200 Samples Subsystem C1 With Failure

S.NO	SUB SYSTEM	SAMPLE RUNS(200)	FAILURES	RELIABILITY
1	C ₁	199	1	0.995
2	C ₁	198	2	0.99
3	C ₁	197	3	0.9850
4	C ₁	196	4	.9800
5	C ₁	195	5	0.975

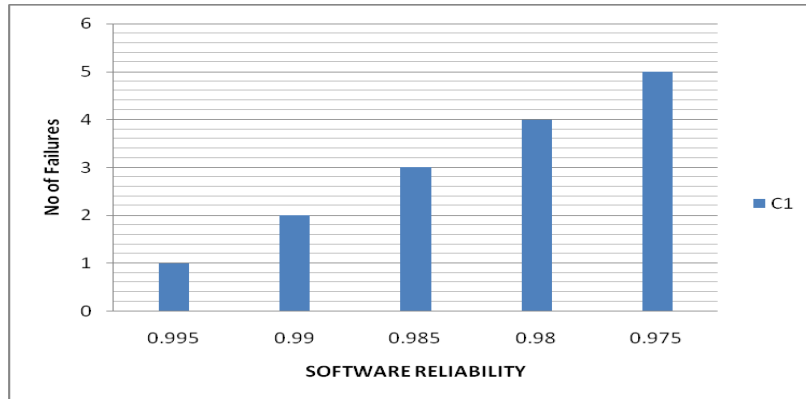


Figure 2 failure ratio of the subsystem C₁

In A above table 1 no of failures are more than 3 then the system reliability is not matching with the required reliability of the system. Failres are should be below three only. The figure 1 shows the failures are increased then the system reliability is not matched with the total system reliability.

If the subsystem C₁ is 200 samples tested without any failure, does the subsystem C₁ meets the requirement? Clearly, the calculation of Eq-3 is not used when there is no failure. Instead of using the MLE estimator, the following binomial equation is used for reliability estimation:

$$1 - CL = \sum_{i=0}^r \binom{n}{i} (1 - R)^i R^{n-i} \quad \text{----- (3)}$$

Here where the 'n' is the sample size, r is the number of failures and CL is the confidence level. Here in the above example we know the sample size n is 200 and the total number of failures are 0. So, we using these values in 7.3 equation then it becomes shown below:

$$1 - CL = R^n \quad \text{----- (4)}$$

Here in the above eq -4 without knowing the value for CL, we cannot solve the above eq-4. If we set the CL value then we will get the R value. By using R value very easily we set the reliabilities of the subsystems reliabilities. Finally we know the reliability of the individual subsystem target reliability requirement is mathing with the total system in advance. For setting the reliabilities in initial level using CL reliability allocation is very essential in the design of any subsystem before development.

Table II Example For The 200 Samples Subsystem C₁ Without Failure With CL

S.NO	SUB SYSTEM	SAMPLE RUNS(200)	RELIABILITY	CL
1	C ₁	200	0.995	0.60
2	C ₁	200	0.99	0.85
3	C ₁	200	0.9850	0.95
4	C ₁	200	0.9840	0.96

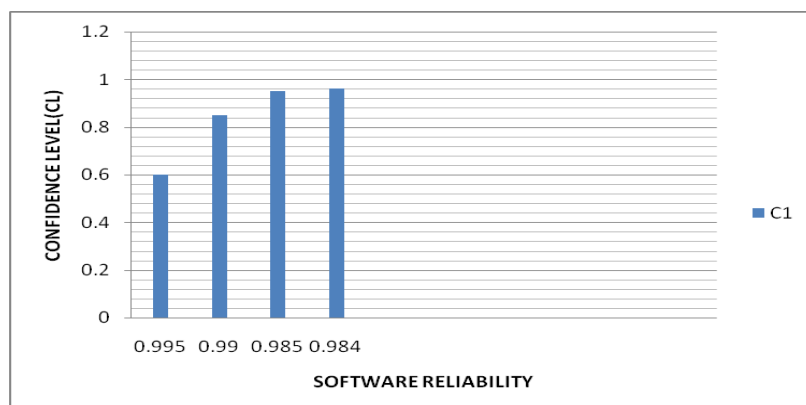


Figure 3 Reliabilities of the subsystem C₁ using CL

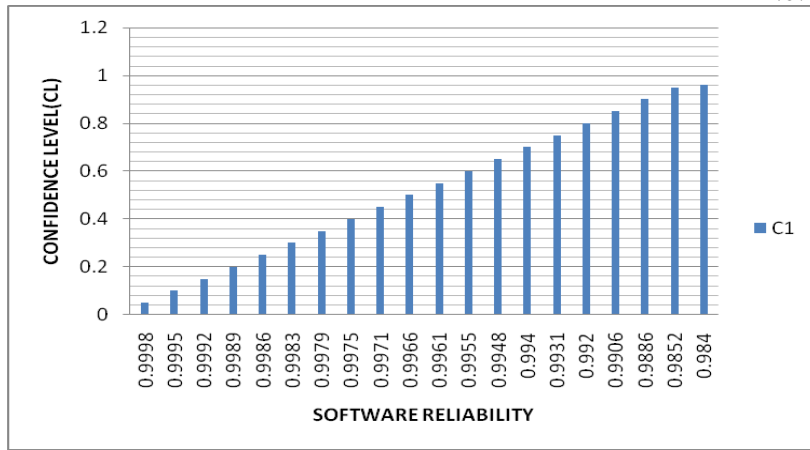


Figure 4 failure ratio of the subsystem C₁ expected failure using CL range starting from 0.05 to 0.96

So that the CL must and should be in the range of 0.05 to 0.96 only. For the above figure 3 shows the failure expected ratio with CL to the particular component. Finally we are proposing a CL is used for setting the reliabilities in an initial level that is design level of software. For the above observations we need to fix the minimum and maximum level of CL. That is given above figure 4. If the CL value of each subsystem should be < 0.96 then the minimum reliability value is 0.984 and the subsystem must be >0.05 then the maximum reliability value is 0.9998. Using the above values we can set the reliabilities in initial level.

Table III Example For The 200 Samples Reliability Of Subsystem C₁ With CL From 0.05 TO 0.96

S.NO	CL	RELIABILITY	S.NO	CL	RELIABILITY
1	0.05	0.9998	11	0.55	0.9961
2	0.10	0.9995	12	0.60	0.9955
3	0.15	0.9992	13	0.65	0.9948
4	0.20	0.9989	14	0.70	0.9940
5	0.25	0.9986	15	0.75	0.9931
6	0.30	0.9983	16	0.80	0.9920
7	0.35	0.9979	17	0.85	0.9906
8	0.40	0.9975	18	0.90	0.9886
9	0.45	0.9971	19	0.95	0.9852
10	0.50	0.9966	20	0.96	0.9840

So that the CL must and should be in the range of 0.05 to 0.96 only. For the above figure 4 shows the failure expected ratio with CL to the particular component. Finally we are proposing a CL is used for setting the reliabilities in an initial level that is design level of software. For the above observations we need to fix the minimum and maximum level of CL. That is given below. If the CL value of each subsystem should be < 0.96 then the minimum reliability value is 0.984 and the subsystem must be >0.05 then the maximum reliability value is 0.9998. Using the above values we can set the reliabilities in initial level.

III. RISK BASED ALLOCATION APPROACH

It is used for measuring the reliability of component without Basic considerations

$$RISK_i = (1 - R_i) * COST_i \text{-----(5)}$$

Reliability allocation with risk constraint then the eq-below is

$$C = \sum C_i - RISK_i \text{-----(6)}$$

$$M_i = C = \sum C_i = -\sum \alpha_i / \ln r_i - RISK_i \text{----- (7)}$$

Total cost of the system will be obtained using the above equation.

Failure of subsystem .Cost of each failure event will depend based on the the size of the component. Using the above eq-(5) we can calculate the development cost without risk cost we are getting the exact cost of the system with required reliability using eq-7.

For this reasons we used the CL for setting the intial reliabilites of the components and we used the novel algorithm for finding the required reliability of the system with minimized cost without risk cost.

Prapose algorithm is used for estimating the development cost with out reisk cost with require reliability is estimated.

Dynamic Risk Management Programming Algorithm:

Step 1: Let S stand for the Reliability matrix is $[r_1, r_2, \dots, r_n]$, and T stand for the price matrix without risk cost $[c_1, c_2, \dots, c_n]$, and 'δ' be the solve footstep length, I_i stand for the matrix with one column and n rows in which simply the value of the I^{th} element is 1 and the rest are all 0. Suppose $S_0 = [\max r \text{ CL}, \max r \text{ CL}, \dots, \max r \text{ CL}]$, $\max r \text{ CL}$ represent the maximized probable reliability based on the CL value. Where the $CL = [0.05-0.96]$ and critical component with Importance of the component, for example 0.9999, which resources the initial reliability standards of the components are all $\max r$ means the all components in the system all are critical components with maximum reliability with low CL.

Here the CL is fixed to all components then all components reliabilities are Maximum using CL.

Step 2: $S_0 \geq R_s(1)$

If the above step is true then only continue otherwise stop and return with no solutions.

Step 3: As for S_0, T_0 and, C_0 can be known by and system reliability R_0 can be known by function F.

Step 4: If $R_0 < R_{obj}$ then stop and return. No solutions.

Step 5: Set Rate = 0;

Step 6: for $i=1$ to n

i) $S' = S_0 - I_i * \delta$;

ii) With regard to S' , Generate reliability R' with the function F, T' with (5), total cost C' with (7), risk cost

iii) $\Delta C = C_0 - C'$; $\Delta R = R_0 - R'$;

iv) if $R' \geq R_{obj}$ and $\Delta C / \Delta R > \text{Rate}$ then Set Rate = $\Delta C / \Delta R$, $R = R'$, $S = S'$, $C = C'$, $T = T'$;

Step 7: if $R_0 \neq R$ then set $S_0 = S$; $R_0 = R$; $C_0 = C$; $T_0 = T$; return to step 5.

Where here the reliability allotment outcome S_0 is the reliability of each component. R_0 and C_0 both two are the similar system reliability and usual system growth price. T_0 is the expected development cost without risk cost allocated to each component. Notice from the above that prerequisite to the correctness of the algorithm is that the decrease in reliability of one component can result in that of the whole system and lower the development cost without required reliability of the system is expected. But that can be guaranteed in our algorithm. The aim of step 6 iv) in the above algorithm is to select an optimal component whose decrease in reliability can result in the maximal cost/reliability variation, which makes the single step programming optimized so that optimal reliability allocation of the ultimate system is guaranteed.

IV. EXAMPLE AND RESULT

Here we choose a system with three independent components r_1, r_2, r_3 . We assume that all the components are essential to the system and their failures are statistically independent. Therefore, the relationship between the total system reliability r and its components' reliability r_i ($i=1, 2, 3$) can be stated as: $r = F(r_1, r_2, r_3) = r_1 * r_2 * r_3$ Suppose that the complexities of the components are 0.30, 0.72 and 0.54 respectively. In order to minimize the system development cost and the system reliability shall be no less than 0.95, how to allocate the reliability to each component without risk cost. Set the precision of computing is 0.01. Such a problem can be rewritten as:
Such a problem can be rewritten as:

$$R_s = r_1 * r_2 * r_3 \leq 0.95$$

$$C_1 = -0.30 / \ln r_1$$

$$C_2 = -0.72 / \ln r_2$$

$$C_3 = -0.54 / \ln r_3$$

Compute the values of parameters (r_1, r_2, r_3) with which the total cost C ($C = c_1 + c_2 + c_3$) is minimized. With respect to each component, we compute the cost with the reliability from 0.95 to 0.99 (increment is 0.01) according to the reliability/cost function model in the data set as shown in Table IV, V, VI.

Table IV Subsystem Cost With Risk And Without Risk Cost Reliability And Dataset ($\alpha_1=0.30$)

s.no	R_1	C_1	$RISK_i$	$M_1 = C_1 - RISK_i$
1	0.95	5.85	0.2925	5.5575
2	0.96	7.35	0.294	7.056
3	0.97	9.85	0.2955	9.5545
4	0.98	14.85	0.297	14.553
5	0.99	29.85	0.2985	29.5515

Table V Subsystem Cost With Risk And Without Risk Cost Reliability And Dataset ($\alpha_1=0.72$)

s.no	R_2	C_2	$RISK_i$	$M_2 = C_2 - RISK_i$
1	0.95	14.04	0.702	13.338
2	0.96	17.64	0.7056	16.9344
3	0.97	23.64	0.7092	22.9308
4	0.98	35.64	0.7128	34.9272
5	0.99	71.64	0.7164	70.9236

Table VI Subsystem Cost With Risk And Without Risk Cost Reliability And Dataset ($\alpha_1=0.54$)

s.no	R_3	C_3	$RISK_i$	$M_3= C_3- RISK_i$
1	0.95	10.53	0.5265	10.0035
2	0.96	13.23	0.5292	12.7008
3	0.97	17.73	0.5319	17.1981
4	0.98	26.73	0.5346	26.1927
5	0.99	53.73	0.5373	53.1927

According to the proposed algorithm above, set initial state S_0 is initial values are based on the CL is given as S_0 with CL 0.05 is $S_0 = [0.99, 0.99, 0.99]$. Accordingly, $T_0 = [29.5515, 70.9236, 53.1927]$, $\delta=0.01$, and the system cost $C_0 = 29.5515 + 70.9236 + 53.1927 = 153.6678$, system reliability $R_0 = 0.99 * 0.99 * 0.99 = 0.97$

Set $i=1, 2, 3$ then compute separately with different value:

- 1) $S' = S_0 - [0.01, 0, 0] = [0.98, 0.99, 0.99]$, $R' = 0.96$, $T' = [14.553, 70.9236, 53.1927]$, $C' = 138.66$, $\Delta C = 15$, $\Delta R = 0.01$, $\Delta C/\Delta R = 1,500$.
- 2) $S' = S_0 - [0, 0.01, 0] = [0.99, 0.98, 0.99]$, $R' = 0.96$, $T' = [29.5515, 34.9272, 53.1927]$, $C' = 117.67$, $\Delta C = 35.99$, $\Delta R = 0.01$, $\Delta C/\Delta R = 3599$.
- 3) $S' = S_0 - [0, 0, 0.01] = [0.99, 0.99, 0.98]$, $R' = 0.96$, $T' = [29.5515, 70.9236, 26.1927]$, $C' = 126.6678$, $\Delta C = 27$; $\Delta R = 0.01$, $\Delta C/\Delta R = 2,700$.

Choose the optimal result 2), set $S_0 = [0.99, 0.98, 0.99]$, continue to perform the same operation :

- 1) $S' = S_0 - [0.01, 0, 0] = [0.98, 0.98, 0.99]$, $R' = 0.95$, $T' = [14.553, 34.9272, 53.1927]$, $C' = 102.6729$, $\Delta C = 14.9971$, $\Delta R = 0.01$, $\Delta C/\Delta R = 1,449.71$.
- 2) $S' = S_0 - [0, 0.01, 0] = [0.99, 0.97, 0.99]$, $R' = 0.95$, $T' = [29.5515, 22.9308, 53.1927]$, $C' = 105.675$, $\Delta C = 11.995$, $\Delta R = 0.01$, $\Delta C/\Delta R = 1,199.5$.
- 3) $S' = S_0 - [0, 0, 0.01] = [0.99, 0.98, 0.98]$, $R' = 0.95$, $T' = [29.5515, 34.9272, 26.1927]$, $C' = 90.6714$, $\Delta C = 26.9986$; $\Delta R = 0.01$, $\Delta C/\Delta R = 2,699.86$

Choose the optimal result 3), set $S_0 = [0.99, 0.98, 0.98]$, continue to perform the same operation :

- 1) $S' = S_0 - [0.01, 0, 0] = [0.98, 0.98, 0.98]$, $R' = 0.94$, $T' = [14.553, 34.9272, 26.1927]$, $C' = 75.6729$, $\Delta C = 14.9985$, $\Delta R = 0.01$, $\Delta C/\Delta R = 1,499.85$.

Hence the all of the results R' are less than the specified reliability target 0.95. Therefore, the reliability allocation in case I & case II R' are greater than the specified reliability target 0.95 and where as in case III all of the results R' are less than the specified reliability target 0.95 and the values are shown below. Finally select the best combination of components with lower cost with required reliability.

CASE (i):

- 1) System reliability allocation $S_0 = [0.99, 0.98, 0.99]$;
- 2) System reliability $R_0 = 0.96$;
- 3) Expected system development cost $C_0 = 117.67$;
- 4) Expected development cost assigned to each components $T_0 = [29.5515, 34.9272, 53.1927]$

CASE (ii):

- 1) System reliability allocation $S_0 = [0.99, 0.98, 0.98]$;
- 2) System reliability $R_0 = 0.95$;
- 3) Expected system development cost $C_0 = 90.6714$;
- 4) Expected development cost assigned to each components $T_0 = [29.5515, 34.9272, 26.1927]$

CASE (iii) is not satisfied with condition:

- 1) System reliability allocation $S_0 = [0.98, 0.98, 0.98]$;
- 2) System reliability $R_0 = 0.94$;
- 3) Expected system development cost $C_0 = 75.6729$;
- 4) Expected development cost assigned to each components $T_0 = [14.553, 34.9272, 26.1927]$.

Hence case III is not applicable.

So that the best combination is shown below:

- 1) Final System reliability allocation $S_0 = [0.99, 0.98, 0.98]$;
- 2) Total System reliability $R_0 = 0.95$;
- 3) Expected system development cost $C_0 = 90.6714$;
- 4) Expected development cost assigned to each components $T_0 = [29.5515, 34.9272, 26.1927]$

V. COMPARISION RESULTS WITH DYNAMIC PROGRAMMING ALGORITHM AND DYNAMIC RSIK MANGEMENT PROGRAMMING ALGORITHM

In this work comparison values are used from the simple series system with the capacity of three components and results are compared with existing DA and proposed DRMPA. Finally at the end effective results are presented using proposed approach.

VI. CONCLUSION

In this paper, reliability allocation and cost estimation for architecture-based software for simple series system was used. The outcome of this work, despite being still preliminary, allows us to say that the method proposed here is a comparatively straight advancing one in conveying the relationship between reliability and cost during design phase. In this paper proposed algorithm DRMPA is efficient and accurate values are comparing with other algorithms and models.

Table VII. Cost And Reliability Dataset ($\alpha_1=0.30$)

s.no	C_1	DA	DRMPA
1	0.95	5.85	5.5575
2	0.96	7.35	7.056
3	0.97	9.85	9.5545
4	0.98	14.85	14.553
5	0.99	29.85	29.5515

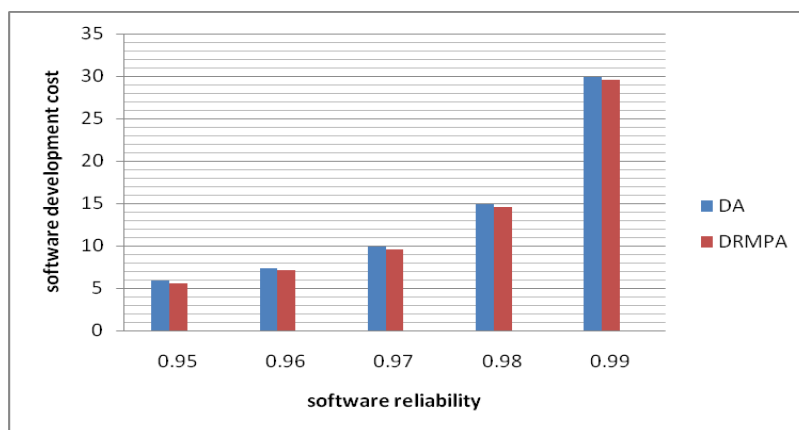


Figure 5. Cost and Reliability Dataset ($\alpha_1=0.30$)

Table VIII Cost And Reliability Dataset ($\alpha_2=0.72$)

s.no	C_2	DA	DRMPA
1	0.95	14.04	13.338
2	0.96	17.64	16.9344
3	0.97	23.64	22.9308
4	0.98	35.64	34.9272
5	0.99	71.64	70.9236

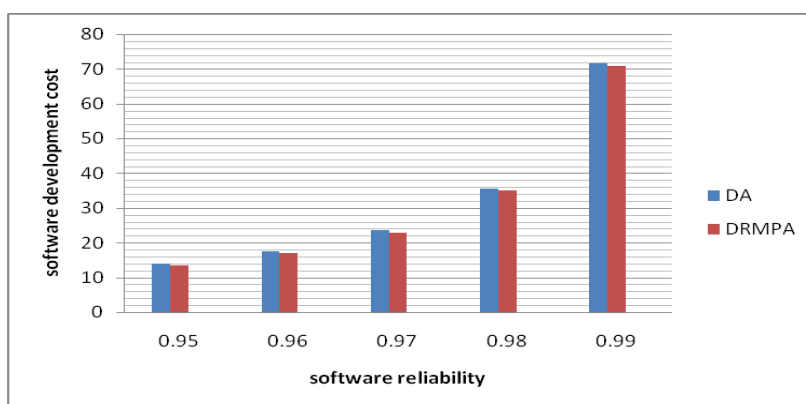


Figure 6. Cost and Reliability Dataset ($\alpha_2=0.72$)

Table IX. Cost And Reliability Dataset ($\alpha_3=0.54$)

s.no	C_3	DA	DRMPA
1	0.95	10.53	10.0035
2	0.96	13.23	12.7008
3	0.97	17.73	17.1981
4	0.98	26.73	26.1927
5	0.99	53.73	53.1927

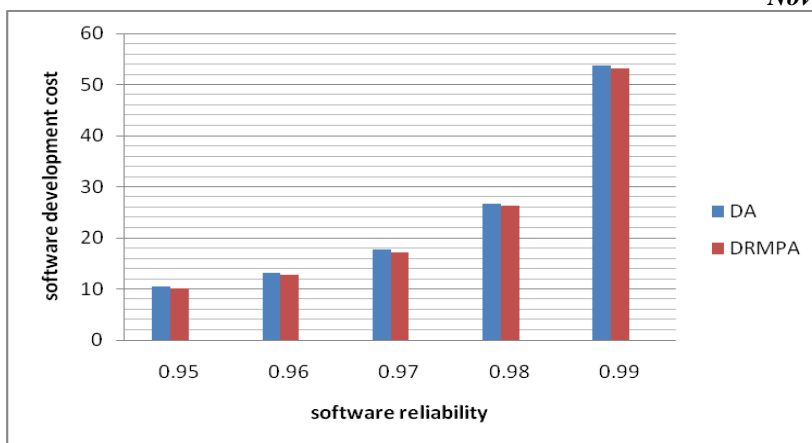


Figure 7: Cost and Reliability Dataset ($\alpha_3=0.54$)

Table X Final Expected System Developmet Cost And The Difference Between DA And DRMPA

S.NO	C1	C2	C3	R	COST
DRMPA	29.5515	34.9272	26.1927	0.95	90.6714
DA	29.85	35.64	26.73	0.95	92.22

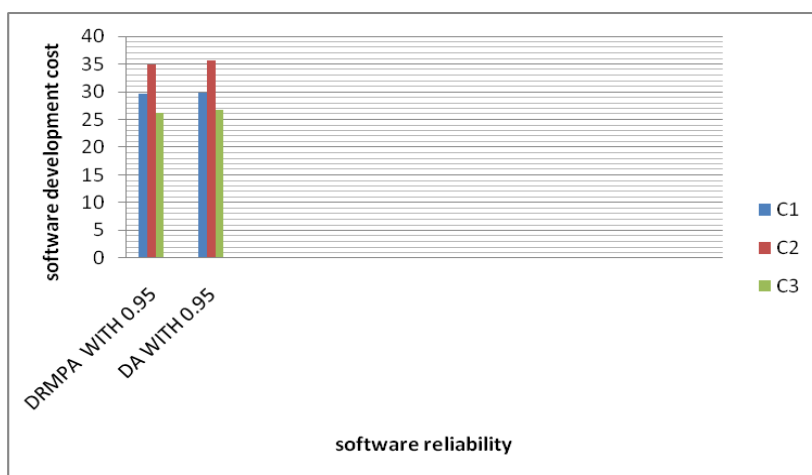


Figure 8: Comparison for C1,C2,C3 with targeted reliability and COST values proposed DRMPA and DA values

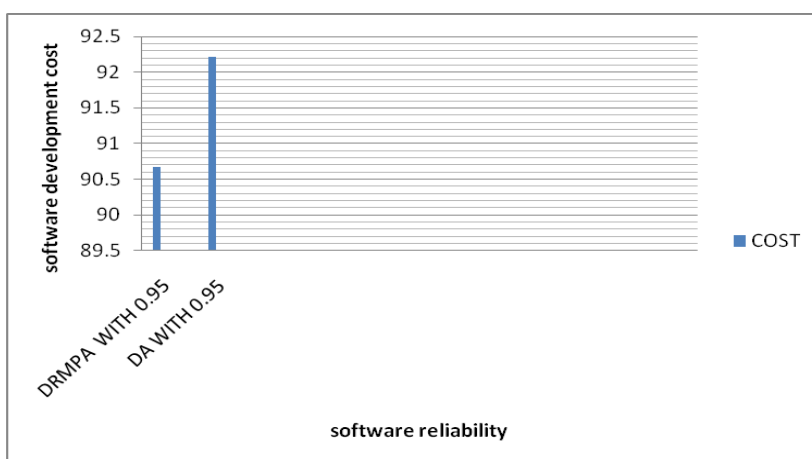


Figure 9: comparison COST total system expected cost for DRMPA approach and DA

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