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## Cost-Efficient Risk Management with Reserve Repair Crew Planning in CLOUD Computing

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#### Abstract

This article addresses a discrete event CLOUD simulator, namely CLOURAM (CLOUD Risk Assessor and Manager) to estimate the risk indices in large CLOUD computing environments, comparing favorably with the intractably theoretical Markov solutions or hand calculations that are limited in scope. The goal is to optimize the quality of a CLOUD operation and what countermeasures to take to minimize threats to the service quality by reserve planning of reserve crew members. Cost and benefit analysis is examined after the solutions.

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Keywords-CLOUD Computing; discrete event simulation; reserve planning; repair (maintenance) crew; cost and benefit; breakeven.

#### 1. Introduction

CLOUD computing, a relatively new form of computing using services provided through the largest network (Internet) has become a promising and lucrative alternative to traditional in-house IT computing services, and provides computing resources (software and hardware) on-demand. Why big firms delay using CLOUD? The response lies in the common belief that companies are hesitant to switch to CLOUD for applications that manage key parts of their businesses due to lack of trust as they believe there is still too much risk associated with potentially unreliable Internet connections and dependence on third parties to manage computer servers (See Wall Street Journal, July 17, 2014; Marketplace: "Why Big Firms Delay Using Cloud" by S. Norton and C. Boulton). Consequently, a quantitative assessment of the quality of service (QoS) in such enterprises is critically needed. The quality of CLOUD computing services can be difficult to measure, not only qualitatively but most importantly

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quantitatively. An algorithmic discrete event simulation accompanied by related statistical inference is conducted to estimate the availability indices in a CLOUD computing environment of small or large service-based systems to mimic real life operations. However, as users (companies, organizations and individual persons) turn to CLOUD computing services for their businesses and commercial operations, there is a growing concern from the security, privacy and availability perspectives as to how those services actually rate. Moreover, the federal government has approved commercial products to operate on a defense CLOUD, marking the industry's first online offerings with this level of security accessible to the military via such an environment [1].

If the reserve capacity (or margin) is less than a zero margin, then we have an undesired deficiency or loss of service. Note that LOLP: Loss of Load Probability. Once these hours (or cycles) of negative margin are added, it will constitute the expected number of hours of loss of load, LOLE. Divided by the total number of exposure units such as 8760 hours (NHRS) for a year, it will give the LOLP = LOLE/NHRS. Once the LOLE is known, and its frequency (f=number of such occurrences of deficiencies per annum), then the average duration, d=LOLE/f, will indicate how long on the average a loss of service is expected to last. What are some of most significant scenarios on "What If" will be studies in subsequent sections, such as what happens when the cloud managers reduce the size of the maintenance crew and at what level should they stop discounting the crew size for best ROI (Return on Investment).

#### 2. CLOUD Resource Management Planning for Employment of Repair (Maintenance) Crews

A most popular example to a what-if query as frequently executed in simulation engineering practices is the resource allocation, which is one of the most vulnerable and softest (weakest) points of the entire CLOUD computing process. We will study the effect of the number of maintenance crews from full to lower. Figure 1 below in the Appendix has originally displayed an unreliability index of 5.44% for 348 units.

The total number of production units is 348 available. In a new analysis, we will simulate (10000 runs or years) for a reduced resource of 100 crews to see the impact. That is how much less reliability we will have to suffice with if we save money by eliminating 248 repair (recovery) crews. This time we are expecting wait times and more unreliability from our CLOUD operation. Now see Figure 2 below in the Appendix. The unavailability index is unfavorably upped to 7.36%, a negligible difference when you take into account the savings you will accrue from employing 248 less repair crews. See Figure 3 below in the Appendix. We now will reduce even further 50 more repair crews, 298 less than originally assumed. Finally so, we will employ solely 50 crews to see if it is economical profitable to do so in Figure 3 below in the Appendix. This time we hit the rock! Outcomes are disastrous. We saw the catastrophic results of a skyrocketing unreliability of 85.71% (while employing only 50 repair crews) from merely 7.36% when we had only 50 more crews. The difference is the breaking point [2]. Therefore this CLOUD management should not lower their repair crews to less than around 100. More detailed studies can be conducted by trying 99....90....70....60 etc. to see the drastic jump. This cost-benefit portfolio of crew-planning analysis as one of the most crucial "What-If" scenarios could save millions of dollars for a CLOUD Resource Management to plan ahead.

#### 3. Step by Step Algorithm CLOUD Management Planning for Employment of Repair Crews

The following software program (CLOUD Management for the manager part of the CLOURAM to follow up with the assessment part) will show you how to do this in a systematic and algorithmic order. Here we will study how to implement the effect of maintenance crews on unavailability index. In this analysis we will simulate for a reduced resource of Crew Intervals (*for example 50, 100, 150 ...*). Consider an example, where the total number of production units available is 443. Now let us simulate for the reduced resource of 50 crews, as in Figure 3 below in the Appendix to see the impact that how unavailability will vary. See Figure 4 below in the Appendix for the input dialogue box. Initially the unavailability varies slightly, at one point it increases in a drastic manner which is called breaking point. The CLOUD should not lower the repair crews to less than the breaking point. We can observe, as in Figure 5 below in the Appendix, the crew break-even point is 143. This cost-benefit portfolio of Reserve Crew Planning analysis will save millions of dollars' worth for a CLOUD Resource Management. In Environment

Parameters Section, three buttons are added which indicates type of execution that is Normal (only risk assessment without management), Crew Planning and Product Planning.

First begin with selecting one among the three types of execution. Normal button is selected to implement a normal execution of Cloud. Crew planning button is selected to implement Reserve Crew Planning and to obtain Crew Plot so as to estimate the optimal crew value to halt at for ensuring certain availability (lack of risk). Product planning button is further selected to implement Reserve Product Planning and to obtain Product Plot so as to find the optimal capacity value to halt at so to ensure a desired availability. Follow the below algorithmic steps to implement Maintenance Crew Reserve Planning:

Step 1: Radio button Crew Planning must be selected as shown in Figure 4 below in the Appendix.

Step 2: # of Crew Increments in default is given as 10, which indicates the number of crew intervals required to plot a graph.

Step 3: Crew Intervals in default is given as 50, which indicates the difference between two crew (working personnel employed) values.

*Step 4*: **ALOLP Crew** in default is given as 0.3, which indicates that if the difference between the two consecutive LOLP values is greater than 0.3, then the crew addition stops at the lowest LOLP value.

Step 5: Starts at Crew is the total number of maintenance crews initially, for data2000.txt there are 443

crews. Step 6: Starts at LOLP Value is the LOLP value for the initial number of maintenance crews.

Step 7: Stops at Crew is the optimal stopping crew value.

Step 8: Stops at LOLP Value is the optimal stopping LOLP value.

Step 9: Final Crew Value is the number of crews that are remaining at the end of the crew planning implementation.

Step 10: Final LOLP Value is the LOLP value for number of crews that are remaining at the end of the crew planning implementation.

*Step 11*: **Cost** in default given as \$1,000,000.00 for a placeholder, which indicates the dollar amount loss to the entire Cloud operation annually as accrued by one percent increase in Loss of Load resulting from sparing the determined number of extra crew members.

*Step 12*: **Benefit** in default given as \$30,000.00, which indicates the dollar amount of investment spent for each new crew member employed per year, hence amount saved when a crew is released.

Now let us see how to implement the effect of maintenance crews on unavailability index. In this analysis we will simulate for a reduced resource of Crew Intervals (*for example 50, 100, 150 ...*). Consider a large cyber CLOUD example, where the total number of available units served by the same number of serving crew units available is 443. Now let us simulate for the reduced resource of 50 crews, as in Figure 5 below in the Appendix to see the impact that how unavailability will vary with the reduction of crew. Initially the unavailability varies slightly; at one point it increases in a drastic manner which is called break-even point. The CLOUD should not lower the repair crews to less than the break-even point. Figure 6 below in the Appendix shows the output for the input dialogue box in Figure 5 below in the Appendix for which using data 2000.txt, the stopping crew value is 143.

**Profit/Loss:** indicates whether there is profit or loss by stopping at the optimal point. If cost of the LOLP increasing is greater than benefit of sparing (saving) repair crew members, then it is Loss (negative value). If cost is less than benefit then it is Profit (positive value).

Break Even Value: indicates the cost per percent for LOLP index required to have neither profit nor loss.

*Step 13:* **Solution** is as follows. Now 300 x 30K = 9,000,000 gained.  $\Delta LOLP = 0.0126$  lost, i.e.,  $0.0126 \times 100\% \times 11M = 1,260,000$ . 9M-1.26 = 7.74M or (+) 7,739,029 exact.

Figure 5's cost-benefit portfolio of Reserve Crew Planning analysis will show to save or lose millions of dollars' worth for a CLOUD Resource Management. It also indicates what the break-even value would be if RHS=LHS in terms of cost and benefit so that the difference (profit or loss) is zero at balance. See Figure 6 below in Appendix for plotting the process. Further, Figure 7 below in Appendix depicts the triplet of operating modes (up, down, waiting) where additionally waiting time is now a reality due to imperfect number of repair crews [3].

#### 4. Some Further Validations of Reserve Crew Planning

When stopping crew value and stopping LOLP value is 0, a message indicates to simulate again with different  $\Delta$ LOLP crew constraint as red-flagged in Figure 8 shown below in Appendix. This message that the analyst needs to enter a new set of feasible input values which is also shown in Figure 9 in Appendix.

#### 5. Discussions and Conclusion

The CLOUD computing as the new century's paradigm change of doing business at a larger scale of computing supported by the internet of all things, must be measured, monitored and managed to see where things are leading to rather than letting it to take charge by the oft-practiced cruise control alternative. The crucial problem with CLOUD computing is its occasional, though dramatic lack of desired availability and security [4]. Once assessed, the next question becomes as to how to manage, rather mitigate the lack of availability. One of the most predominant measures to do that is the leverage of maintenance crews. Where do we halt recruiting the maintenance the repair crews and what is the breakeven value of the number of crews that need to be kept ready for service to monitor the desired availability at best? Once can certainly not achieve this cost optimization by sheer guessing or hand calculating. This research shows through the related software how best to achieve cost optimal reserve planning for the maintenance crews, a process which can cost CLOUD managing or facilitating companies millions of dollars if not rightfully estimated in advance [5].

### Appendix:

Producers-			System Load Para	meters				Environment Parameters					
Group:	25	Submit	Constant Load				Maintance Crews	348 (	Standard	🖲 Exp	q 5.0630		
Components:	1				A	dd Loads	Total Cycles (TC	8760	Power	O Weibu	M 2.5050		
Product Value:	1	Delete	O Percent Load		Ad	d to Range	Simulations		Cyber	O Mixed			
			Variable Load	d Delete Range			Lamda0		Cyber	O Mixed	Up Dow		
Weibuli Sildpe.		Contraction of the second	-		Multiply Range					Values			
Failure Rate:	.01	O Wei Dist	Multiplier:	1.0			MuO	: 0.000001					
Repair Rate: .02			Startup Failure	0.0000001	Modify Range	Time:	0 hr 2 min 50 s			Graph			
			Startup Delay	0				0111 211111 001			Density		
				y f(y)		F(y)	S(y)	x f(x	)	F(x)	S(x)		
			-	Average Durat	ion of load	surpluses: s	= 43 5432	Average Dura	ation of load	deficiencies	: d = 2 5050		
Simulation Syster	m Results	5		Frequency of I			- 10.0102	Average Duration of load deficiencies: d = 2.5050 Frequency of load deficiencies: f = 190					
Repair Crews: 34				Standard Devi			Standard Deviation = 108.93829248						
Component Grou	ps: 24			Total cycles of	lus Expected	LSE = n * s = 8283	Total cycles of Loss Of Load Expected: LOLE = f* d = 476						
Fotal number of c				Load Surplus	LSP = LSE/	C = 0.9456	Loss of load probability: LOLP = LOLE/TC = 0.0544						
Total installed capacity: 20950 Load Applied: Variable							SPU = 42652741	Expected Unserved Production Units: EUPU = 610707 Total cycles without surplus or deficiency (ties): 0					
				Total cycles w	ithout surpl	us or deficie	icy (ties): 0						
Production Unit: 0	Capacity *	Cycle		00000000000									
				q2: 239.5658				q1: 5.0630	2				
				theta2: 0.9958				theta1: 0.802					
Component Sum				alpha2: 0.182	5			alpha1: 0.616	05				
Component Sum	mary				f(y)	F(y)	S(y)		f(x)	F(x)	S(x)		
				Avg. Up	Density	Cum.	Survival	Avg. Down	Density	Cum.	Survival		
Group Name: 1				Duration	Denoig	Density	Carrina	Duration	Denoty	Density	ourman		
Component: 1 C	apacity: 3	340		Cycles		Denong		Cycles		Denoty			
		325 out of 8760 cyc	des,	0									
resulting in an average of 1980500 production units.			1	0.1818	0.1818	0.8182	1	0.4948	0.4948	0.5052			
				2	0.0905		0.7277	2	0.1985	0.6933	0.3067		
				3 4	0.0601		0.6677		0.1062	0.7995	0.2005		
		Average cycles not produced due to repair: 2929			0.0449		0.6228	4	0.0639	0.8634	0.1366		
Average cycles		Average cycles not produced due to wait: 0. Average cycles not produced due to startup faliure: 0.			0.0357		0.5870	5	0.0410	0.9045	0.0955		
Average cycles Average cycles	not produ		6-11		0.0297		0.5574	6	0.0274	0.9319	0.0681		
Average cycles Average cycles Average cycles	not produ not produ		faliure: 0.	5	0.0050								
Average cycles Average cycles Average cycles Average cycles Availability: 0.665	n <mark>ot produ</mark> not produ 0		faliure: 0.	7	0.0253		0.5320						
Average cycles i Average cycles i Average cycles i Availability: 0.665 Jnavailability: 0.3	not produ not produ 0 350		faliure: 0.	7 8	0.0221	0.4900	0.5100	8	0.0133	0.9640	0.0360		
Average cycles i Average cycles i Average cycles i Availability: 0.665i Unavailability: 0.3 Failure rate: 0.021	not produ not produ 0 350 30		faliure: 0.	7 8 9	0.0221 0.0195	0.4900 0.5095	0.5100 0.4905	8	0.0133 0.0095	0.9640 0.9735	0.0360 0.0265		
Average cycles i Average cycles i Average cycles i Availability: 0.665i Unavailability: 0.3 Failure rate: 0.021	not produ not produ 0 350 30		faliure: 0.	7 8 9 10	0.0221 0.0195 0.0175	0.4900 0.5095 0.5270	0.5100 0.4905 0.4730	8 9 10	0.0133 0.0095 0.0068	0.9640 0.9735 0.9803	0.0360 0.0265 0.0197		
Average cycles	not produ not produ 0 350 30		faliure: 0.	7 8 9	0.0221 0.0195	0.4900 0.5095 0.5270 0.5429	0.5100 0.4905	8	0.0133 0.0095	0.9640 0.9735	0.0360 0.0265		

Figure 1. The simulation results (1,000 years) for a large CLOUD with 348 units. Run time: 2 min 5s.

Group: 1 Submit Order Order Submit Order Order Submit Order	em Load Paran Constant Load Percent Load Variable Load tiplier: tup Failure tup Delay	1.0 0.0000001 0	Add Del	Id Loads I to Range ete Range tiply Range dify Range	Environment Pau Maintance Crew Total Cycles (T Simulation Lamda Mu Time:	rs 2) s: 0; 0;	100 © 8760 ◯	Standard Power Cyber	<ul> <li>Exp</li> <li>Weibu</li> <li>Mixed</li> </ul>	NB Parameters 7.9426 M 3.3503 0 d E Up © Down Values Graph Density S(x)
Simulation System Results Repair Crews: 100 24 Total number of component: 348 Total installed capacity: 20950 Load Applied: Variable Production Unit: Capacity * Cycle		Load Surplus Pre	d surplus on = 116. oad Surpli obability: I s Product	es: n = 193 86735465 us Expecte LSP = LSE/ ion Units: E	LSE = n * s = 8115 FC = 0.9263 SPU = 41550257		Loss of load pr	ad deficier tion = 116. Loss Of Lo obability: L rved Produ hout surple	ncies: f = 19 78556189 ad Expecte OLP = LOL iction Units	3 d: LOLE = f* d = 645 E/TC = 0.0736 EUPU = 1110832
Component Summary Group Name: 1 Component: 1 Component: 1 Carbon to 1 Produced an average of 5694 out of 8760 cycles. I average cycles not produced due to repair 2882 Average cycles not produced due to repair 2882 Average cycles not produced due to startup failure Average cycles not produced due to startup failure Unavailability: 0.3500 Failure rate: 0.0552	s. a: O.	y         fty)         F(y)         3           Avg. Up Duration         Density         Cum. S         Cum. S           Duration         0.1831         0.1831         0.           1         0.1831         0.1831         0.           3         0.0605         0.3347         0.           4         0.0452         0.3347         0.           5         0.0360         0.4159         0.           6         0.0225         0.4457         0.           7         0.0225         0.4934         0.           9         0.0126         0.5336         0.           10         0.0176         0.5306         0.			S(y) Survival 0.8169 0.7258 0.6653 0.6201 0.5643 0.5643 0.5658 0.5065 0.4594 0.4694 0.4694		xyg. Down Duration Cycles 1 2 3 4 5 5 6 7 8 9 10	f(x) Density 0.4218 0.1844 0.0704 0.0492 0.0269 0.0206 0.0160 0.0126	F(x) Cum. Density 0.4218 0.6062 0.7136 0.7840 0.8333 0.8691 0.8960 0.9166 0.9325 0.9451 0.9551	S(x) SU(rvval 0.5782 0.3938 0.2864 0.2864 0.1807 0.1607 0.1309 0.1309 0.1309 0.0834 0.0854 0.0854 0.0854 0.0854 0.0854 0.0854

Figure 2. The simulation results (1,000 years) for a large CLOUD with 348 units for 100 repair crews.

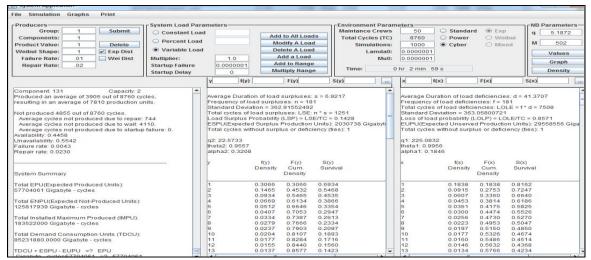
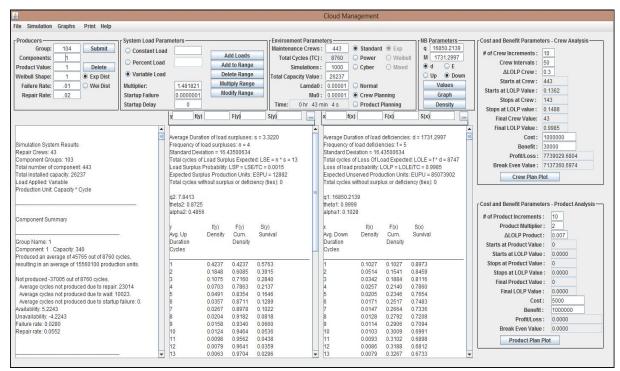


Figure 3. The simulation results (1,000 years) for a large CLOUD with 398 units for 50 repair crews.

100		Cloud Management	
File         Simulation         Graphs         Print         Help           Producers         T         Submit         Submit	tystem Load Parameters Constant Load Add Loads Add Load	Cloud Management	Bit Orazametera       Cost and Benefit Parametera         # of
Repair Rate: 02 5	Startup Failure 0.0000001 Modify Range	Mu0: 0.00001 @ Crew Planning	Coragin Density Storts at LOL Value : Final Crew Value: Final Crew Value: Final Crew Value: Final Crew Value: Final Crew Value: Crew Plan Plat. Crew Plat. Crew Plan Plat. Crew Plat. Crew Plan Plat. Crew Pla
			Stopp at Product Value : Stopp at LOLP Value : Final Product Value : Final LOLP Value :

Figure 4. The dialogue box input data example for specifically crew reserve planning .



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Figure 5. Output dialogue box for Input Data in Figure 4 for 1000 simulations with 443 repair crews.

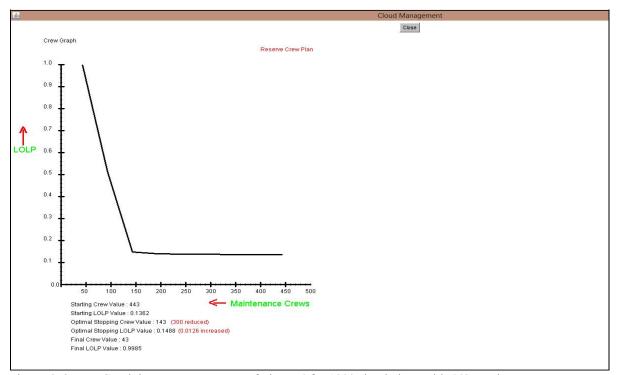


Figure 6. Output Graph in response to Input of Figure 4 for 1000 simulations with 443 repair crews.

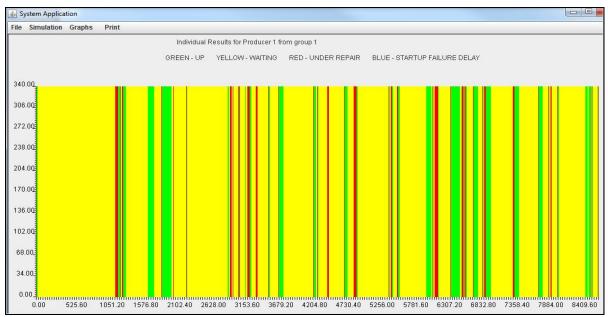


Figure 7. The sequences of up (green), down (red) and yellow (waiting) for Group1's Unit1 history.

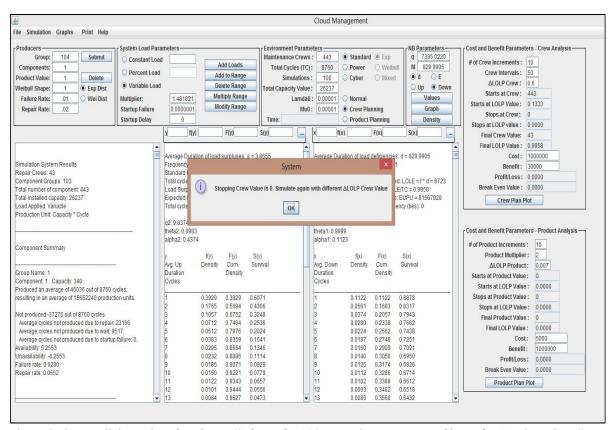


Figure 8. Output dialogue box for Figure 4's input for 100 runs when a new set of input for " $\Delta$ LOLP Crew" required as above.

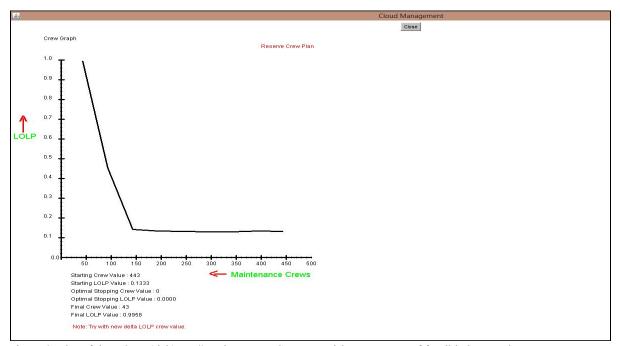


Figure 9. Plot of the LOLP (risk) vs. # Maintenance Crews requiring a new set of feasible input values.

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