RELIABILITY CENTERED MAINTENANCE BASED ON DEMPSTER-SHAFER APPROACH

(CASE STUDY ON PETRA CHRISTIAN UNIVERSITY'S COMPUTER CENTER)

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Abstracts

Reliability Centered Maintenence (RCM) is a sistematic maintenence strategy based on a system reliability. Application of RCM process will not always come out with a binary output of "yes" and "no". Most of the time they are not supported with available detail information to calculate system reliability. Therefore Dempster-Shaffer approach to RCM (DS-RCM) will help organization to model the uncertainties. Expert weighted recommendation for RCM will take count evidence measure, beliefs and plausibility. DS-RCM is applied to Petra's Christian University's Computer Center to find the best maintenence strategy with a limited human resource available.

Keyword: Reliability Centered Maintenence, Dempster-Shaffer RCM

Introduction

Reliability Centered Maintenence (RCM) is a sistematic maintenence strategy based on a system reliability.RCM focused on failure prevention to maintain system's functionality. The goal is to develop a maintenence strategy fit with current and future condition. Application of RCM process will not always come out with a binary output of "yes" and "no". Most of the time they are not supported with available detail information to calculate system reliability.

Therefore Dempster-Shaffer approach to RCM (DS-RCM) will help organization to model the uncertainties. Expert weighted recommendation for RCM will take count evidence measure, beliefs and plausibility. These recomendation will be used to find the best maintenence strategy.

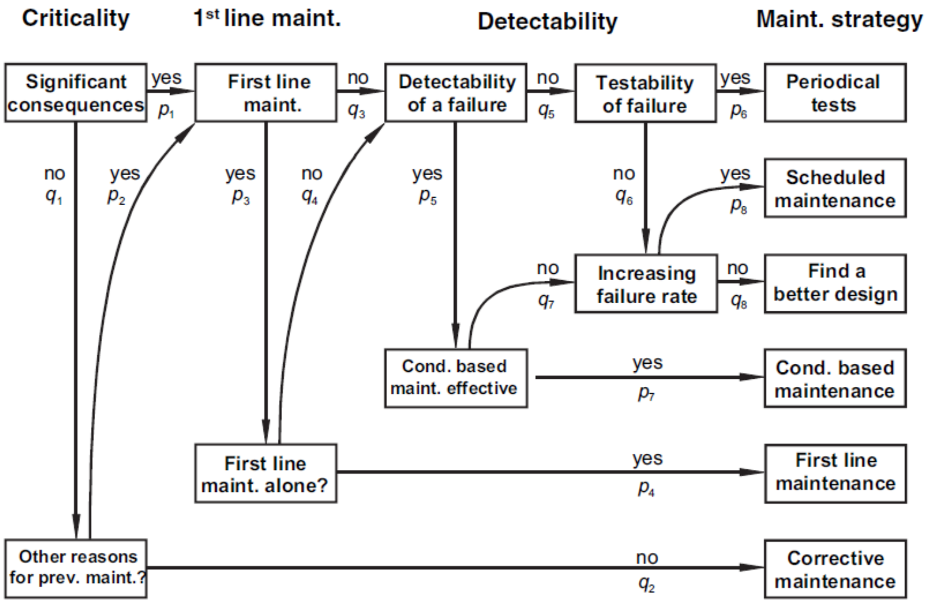
Petra's Christian University's Computer Center (PCU-CC) responsible to all computer hardware and software maintenence wich consist of two thousands PC with only five human resource. Two days repaire time target often cannot be achieved due to limited human resource available. DS-RCM is applied to find the best maintenence strategy for PCU-CC.

RCM based on Dampster-Shaffer Approach

RCM is a process used to determined the maintenence requirements of any physical assets in its operating contex [1]. RCM has been used in the airline industry since 1970s and has been developed into non-aviation industry (nuclear power plants, oil refineries, water treatment plants, etc.). There are seven basic RCM questions:

1. What are the functions of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?

6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?
These seven questions resulted RCM decission diagram which will facilitate the choice of optimum maintenence strategy.



Graphic 1. Example of RCM Decission Diagram

RCM itself has three approach: qualitative, probabilistic, and fuzzy approach. Qualitative has its draw backs due to concensus requirements on each questions and does not provide a ranking of strategies. Probabilistic approach interpret the degree of an expert's belief as the mean value for a decission. Fuzzy aproach allows subjective assessment and expert experience as a fuzzy input variables.

Dampster-Shaffer Theory (DST), which also known as belief function theory, is a generalization of Bayesian theory for subjective probabilities. DST introduced in the field of reliability in the early 1990s. It is based on a scenario that contains the system with all hypotheses, pieces of evidence and data sources. The hypotheses represent all possible states in the system. Pieces of evidence are symtoms or events that occur or may occur in the system. Data sources are persons or organizations that provide information for a scenario. There are several terms used in DST:basic assignment (m), belief (bel), and plausibility (pl).

$$bel(\boldsymbol{A}) = \sum_{B \subseteq A; B \neq \phi} m(\boldsymbol{B}) \quad (1)$$

$$pl(\boldsymbol{A}) = \sum_{B \cap A \neq \phi} m(\boldsymbol{B}) \quad (2)$$

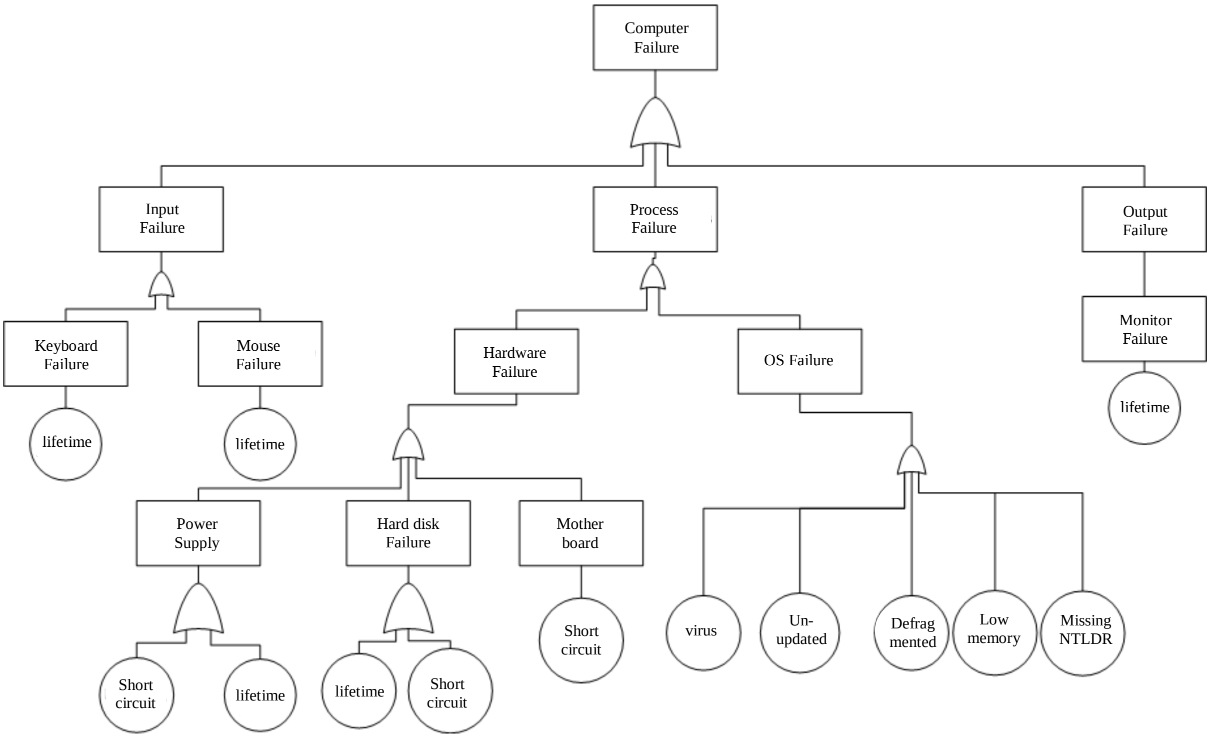
$$m_{1,2}(Z) = \frac{\sum_{A \cap B = Z \neq \emptyset} m_1(A) m_2\ (B)}{1 - \sum_{A \cap B = Z \neq \emptyset} m_1(A) m_2\ (B)} \quad (3)$$

Research Methodology
The research started with computer failure identification on PCU-CC, wich can be classified into input failure, process failure, and output failure. Process failure itself can be differentiated as hardware failure and operating system failure. Different failure will required

different repaire procedure and maintenence strategy. Fault Three Analysis (FTA) will be conducted to analyse computer failure root cause.

Data are collected by interviewing PCU-CC maintenence experts. Uncertainty found in this interview will be combined to measure beliefs and plausibility for each maintenence strategy using DS approach. The result of this DS-RCM for PCU-CC will be a weighted maintenence support for each computer failure. A maintenence strategy for PCU-CC will be designed based on this information.

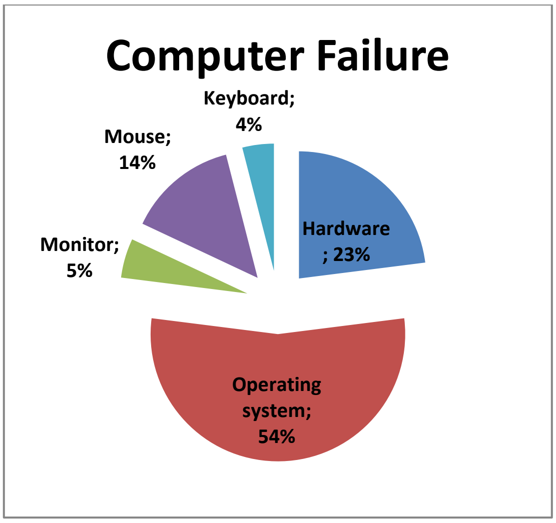
Failure Identification



Graphic 2. Computer Failure Fault Tree Anaysis

Computer failure can be differentiated as input failure (keyboard and mouse), output failure (monitor) and process failure (hardware failure and operating system failure). Hardware failure itself consist of power supply failure, hard disk failure, and motherboard failure. Sort circuit is the main cause of failure for power supply, hard disk and motherboard. While product lifetime is also caused failure except for motherboard. Operating system failure caused by virus infection, un-updated anti virus, defragmanted memory, low free memory space, and missing NTLDR.

Input failure (mouse and keyboard) and output failure (monitor) is usually caused by product lifetime. PCU-CC use replacement policy as failure handling for keyboard, mouse and monitor (total of 23%). Even if mouse, keyboard and monitor still can be repaired, PCU-CC will repair them to be used next time as backup. This research will focused on maintenence strategy for process failure which happend to CPU hardware (23%) and operating system (54%).



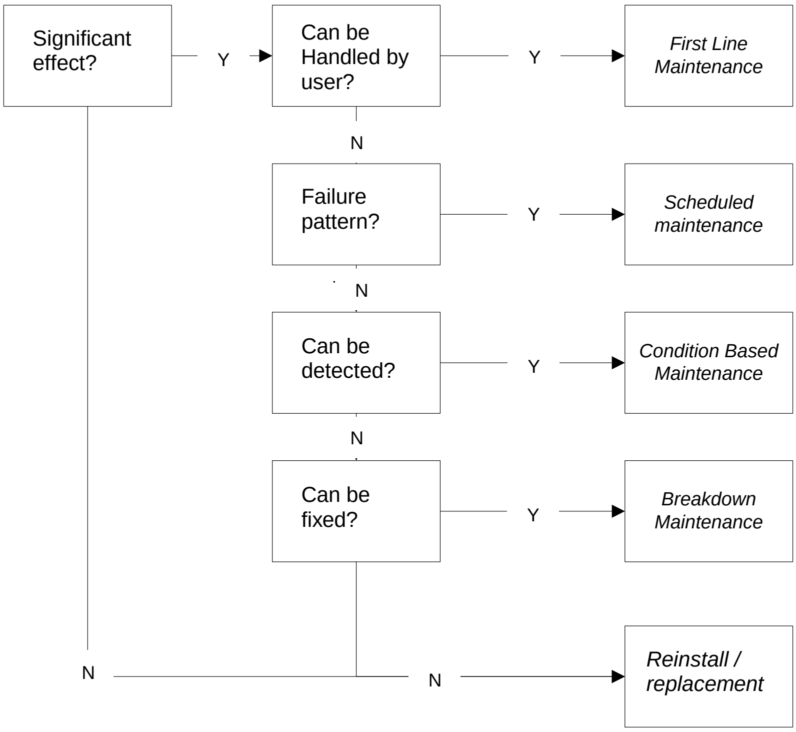
Graphic 3. Computer Failure Percentage

RCM Failure Decission

RCM failure decission diagram is created by PCU-CC expert as hypotheses of all possible states in the system. There are five questions need to be answered from this diagram:

1. Failure give significant effect?
2. Failure can be handled by user?
3. Failure with pattern?
4. Failure can be detected?
5. Failure can be fixed?

The result are five maintenence strategies which can be applied to the system. First line maintenence is done by user, while other strategies done by PCU-CC staff based on schedule, condition or performance.



Graphic 4. RCM Decission Diagram for Computer Failure

DST-RCM Approach

Data are collected based on interview with two experts of PCU-CC for each failure on hardware and operating system. There are five questions ask based on RCM decission diagram to each expert which have to be answered with basic asignment of “yes”, “no” and “uncertain”.

Data example for virus infection by first expert (M1) and second expert (M2)

$$M1 = \begin{bmatrix} 0{,}6 & 0{,}2 & 0{,}2 \\ 0{,}8 & 0{,}1 & 0{,}1 \\ 0{,}9 & 0 & 0{,}1 \\ 0{,}8 & 0{,}1 & 0{,}1 \\ 0{,}95 & 0{,}05 & 0 \end{bmatrix} \qquad M2 = \begin{bmatrix} 0{,}7 & 0{,}2 & 0{,}1 \\ 0{,}7 & 0{,}2 & 0{,}1 \\ 0{,}8 & 0{,}2 & 0 \\ 0{,}9 & 0{,}1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

Combination result for first question

$$C1 = \begin{bmatrix} 0{,}42 & \cancel{0{,}14} & 0{,}14 \\ \cancel{0{,}12} & 0{,}04 & 0{,}04 \\ 0{,}6 & 0{,}02 & 0{,}02 \end{bmatrix}$$

Focal sum

$\sigma = 1 – 0{,}14 – 0{,}12$

$\sigma = 0{,}74$

$$m_1(A_1) = \frac{0{,}6\times0{,}7+0{,}2\times0{,}7+0{,}6\times0{,}1}{0{,}74} = \frac{0{,}62}{0{,}74} = 0{,}84$$

$$m_1(A_2) = \frac{0{,}2\times0{,}2+0{,}1\times0{,}2+0{,}2\times0{,}2}{0{,}74} = \frac{0{,}1}{0{,}74} = 0{,}13$$

$$m_1(A_3) = \frac{0{,}2\times0{,}1}{0{,}74} = \frac{0{,}02}{0{,}74} = 0{,}03$$

bel1 (A1) = 0,84

pl1 (A1) = 0,87

bel1(A2) = 0,13

pl1 (A2) = 0,16

Table 1. Belief and Plausibility for Computer Failure

	Answer "Yes"		Answer "No"	
	Bel (A1)	Pl (A1)	Bel (A2)	Pl (A2)
Question1	0,84	0,87	0,13	0,16
Question2	0,922	0,935	0,065	0,078
Question3	0,97	0,97	0,03	0,03
Question4	0,97	0,97	0,03	0,03
Question5	1	1	0	0

Table above is a collection of belief and plausibility for each questions. For example I1,1 [0,84 ; 0,87] is the value of belief and plausibility "yes" answer for question 1, while I1,2 [0,13 ; 0,16] is the value of belief and plausibility "no" answer for question 1.

Weighted maintenence strategy based on belief and plausibility calculated:

- Strategy 1 (R1) = I1,1 * I2,1
- Strategy 2 (R2) = I1,1 * I2,2 * I3,1
- Strategy 3 (R3) = I1,1 * I2,2 * I3,2 * I4,1
- Strategy 4 (R4) = ((I1,1 * I2,2 * I3,2 * I4,2) +I1,2) *I5,1
- Strategy 5 (R5) = ((I1,1 * I2,2 * I3,2 * I4,2) +I1,2) *I5,2

R1 = [0,84 ; 0,87] [0,922 ; 0,935]
R2 = [0,84 ; 0,87] [0,065 ; 0,078] [0,97 ; 0,97]
R3 = [0,84 ; 0,87] [0,065 ; 0,078] [0,03 ; 0,03] [0,97 ; 0,97]
R4 = [[0,84 ; 0,87] [0,065 ; 0,078] [0,03 ; 0,03]+[0,13 ; 0,16]] [1 ; 1]
R5 = [[0,84 ; 0,87] [0,065 ; 0,078] [0,03 ; 0,03]+[0,13 ; 0,16]] [0 ; 0]

R1 = [0,7728 ; 0,8135]
R2 = [0,053 ; 0,066]
R3 = [0,0016 ; 0,002]
R4 = [0,13 ; 0,16]
R5 = [0 ; 0]

Based on this result, recomendation for virus infection is strategy 1 (R1) which is first line maintenence done by user. This is based on the highest minimum and maximum support for R1. The same calculation done for other failure in PCU-CC.

Table 2. Maintenence Strategy for Computer Failure

	Hard disk failure	**Motherboard failure**	**Power supply failure**	**Memory failure**	**Virus infection**	**Missing NTLDR**
R1	[0 ; 0]	[0 ; 0]	[0 ; 0]	[0,0658 ; 0,0752]	**[0,7728 ; 0,8135]**	[0 ; 0]
R2	[0,11 ; 0,12]	[0 ; 0]	[0 ; 0]	**[0,717 ; 0,752]**	[0,053 ; 0,066]	**[0,99 ; 1]**
R3	**[0,677 ; 0,712]**	**[1 ; 1]**	**[1 ; 1]**	[0,121 ; 0,149]	[0,0016 ; 0,002]	[0 0,01]
R4	[0,012 ; 0,016]	[0 ; 0]	[0 ; 0]	[0,0072 ; 0,107]	[0,13 ; 0,16]	[0 ; 0]
R5	[0,011 ; 0,015]	[0 ; 0]	[0 ; 0]	[0,0528 ; 0,054]	[0 ; 0]	[0 ; 0]

Conclusion

DS-RCM has been applied to Petra's Christian University's Computer Center to find the best maintenance strategy with a limited human resource available. Condition Based Maintenance is recomended for hard disk, motherboard and power supply failure. While scheduled maintenance best applied for missing NTLDR. Virus infection recovery should be done by first line maintenance.

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