IMPLEMENTING DMG MODEL TO IMPROVE RELIABILITY OF PERSONAL COMPUTER AT COMPUTER LABORATORY FACILITY

Emon Azriadi[1], Aris Fiatno[2]
[1&2]Program Studi Teknik Industri Universitas Pahlawan Tuanku Tambusai
Email : eazria10@gmail.com
abi.fiat@gmail.com

ABSTRACT

A typical maintenance organisation has responsibility in keeping the production facility running at the desired level performance. In order to ensure that condition, necessary decisions should be made. The Decision Making Grid (DMG) model is one of analysis technique that provides maintenance organisation in strategic and tactical level management to determine the appropriate maintenance policy for all individual machinery and equipment within the facility. In this project, the analysis identified the performance of the personel computer at laboratory facility by conducting availability measurement. The hardware, peripheral, and softwarewhich have breakdown records were analysed then by the DMG model to propose the appropriate maintenance policy for all individual personel computer within the computer laboratory facility. Implementing the DMG recommendations were proposed to follow the suggested priority order.

Keywords: *breakdownfrequency, downtime, maintenace policy*

1. Background

Maintenance of industrial manufacturing can be defined as all necessary activities to keep an equipment or system in, or restore it to, a condition in which it can perform its required function (Monchy, 1991; Pintelon and Gelder, 1992). Similar with the statement, Abazi and Sassine (2001)explained that the main purpose of maintenance in industry is to keep a system's facilities in functioning state, to reduce the adverse effects of breakdown and to increase the availability of the assets.

In the meantime, industrial manufacturing systems are always changing due to the advancement in technology. Many industrial manufacturing are sometimes designed to be operated in critical condition, and the tendency of the failure is likely to continue under the competitive demands of marketplace. An effective maintenance becomes crucial for keeping the reliable production facility and for ensuring the fulfilment of the production target.

In this case of this project, the analysis identified the performance of the personel computer at laboratory facility by conducting availability measurement. The hardware, peripheral, and softwarewhich have breakdown records were analysed then by the DMG model to propose the appropriate maintenance activities for all individual personel computer within the computer laboratory facility. Implementing the DMG recommendations were proposed to follow the suggested priority order.

1.Objective

To provide a cost effective maintenance strategy, a decision support analysis could be helpful. It can assist the maintenance manager to make certain appropriate decisions to maintain the assets in the state of desired level performance.

One of the decision analysis techniques that can be used is the Decision Making Grid (DMG) model. This technique has been utilised in many industrial sectors to provide the maintenance manager a suitable maintenance strategy for machinery and production equipment. For example, the DMG model was applied in an automotive manufacturing company by Labib (1996) and also in a food processing company by Burhannuddin (2007).In this research, a conventional Computer Laboratory of UniversitasPahlawanTuankuTambusai is considered to apply the DMG model as decision support technique in their maintenance organisation.

3.1 Decision Making Grid Model

Labib (2004) proposed the DMG model as a map on which the performances of the worst machines are mapped according to multiple criteria. It defines DMG in control chart on two dimension model. First model is downtime with low, medium and high criterion, and the second is frequency of failure as low, medium and high criterion. The methodology has implemented as follows:

Step 1: Criteria Analysis - Establish a Pareto analysis of the two factors, downtime frequency and machine downtime;

Step 2: Decision Mapping - Those machines that meet both criteria and ranked in step 1, are then mapped in the two dimensional matrix, and;

Step 3: Once mapping been finalised, the decision is developed by comparing the two dimensional matrix developed in step 2 with DMG as shown in figure 5.

Figure 5 DMG model mapping (Source: Labib, 2004).

The objectives of this application are to implement appropriate strategies that will lead to the

Decision-Making Grid		Downtime		
		Low	Medium	High
Frequency	Low	(OTF)	(FTM)	(CBM)
	Medium	(FTM)	(FTM)	(FTM)
	High	(SLU)	(FTM)	(DOM)

movement of machines towards an improved maintenance stages, complied with respect to the multiple criterion maintenance policies as follows:

- *Operate to failure (OTF): Machine is very seldom failed. Once failed, the downtime is short;*
- *Fixed time maintenance (FTM): Failure frequency and downtime are almost at the moderate cases;*
- *Skill levels upgrade (SLU): Machine is always failed. But it can be fixed very fast;*
- *Condition-based maintenance (CBM): Machine is very seldom to fail. But once failed, it takes a long time to bring it back to the normal operation;*
- *Design out maintenance (DOM): Machine is always failed. Once failed, it takes a long time to bring it back to the normal operation.*

Labib (2004) also recommended that Total Productive Maintenance (TPM) approach should be applied for lower triangle of the DMG matrix as shown in figure 6. TPM is applied widely in Japanese factories and one of the TPM concepts is to empower the operators to maintain continuous productions on totally efficient lines. The approach of TPM is the continuous knowledge transfer to operators and maintains the production machines together with the maintenance crew. Hence, slowly it can reduce waiting times for technicians to be in the production plant. Also, it gives the opportunities to operators to eliminate the root causes of machines errors at the small level, before they become big ones.

Furthermore, it is mentioned that Reliability Centred Maintenance (RCM) approach should be applied for upper triangle of the matrix as shown in figure 6. It explained that RCM involved inspections and measurements of the probability that a machine will operate as expected as desired level, for a specific period of time under the design operating conditions without any failures. Once those problematic machines are identified, then maintenance strategy should be adjusted to ensure the longest *survival of the machine to complete a mission at specific time. Strategies such as condition-based monitoring or design out maintenance could be executed based on the measurement and estimates.*

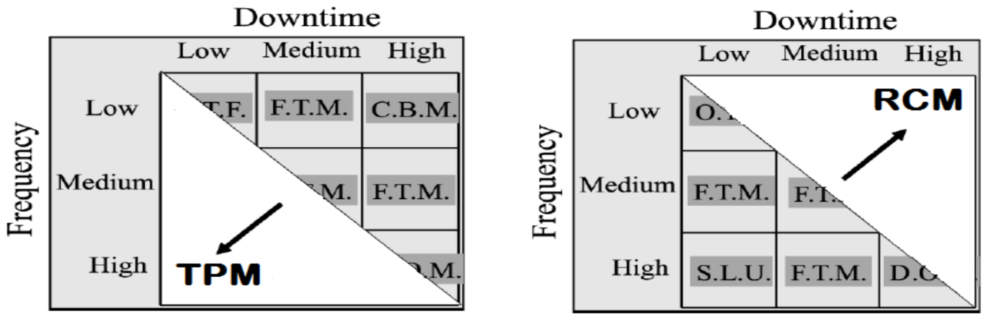

Figure 6 DMG-TPM and RCM Strategy
(Source: Labib, 2004)

The significance of this approach is that rather than treating RCM and TPM as two competing concepts, it unifies them within a single analytical model, fixed time maintenance (FTM). In general, the easy FTM questions are "Who?", and "When?" (the efficiency questions). The more difficult ones are "What?" and "How?" (the effectiveness questions), as indicated in figure 7 (Labib, 2004).

Figure 7 DMG-Easy FTM and DMG-Difficult FTM Strategy
(Source: Labib, 2004)

One of the advantages of the DMG model is able to address many maintenance decision policies, for example DOM. CBM, FTM, SLU and OTF to individual equipment and machinery in a complex system which were used for analysis.

Decision-Making Grid		Downtime		
		Low	Medium	High
Frequency	Low	(OTF)	When?	(CBM)
	Medium	Who?	Easy FTM / Difficult FTM	What?
	High	(SLU)	How?	(DOM)

4. Availability Measurement

In order to analyse the data investigated from a conventional Computer Laboratory of UniversitasPahlawanTuankuTambusai, the selected company, the author determines few main function characteristics, and these are given as follows:

1. *The available time of operational records in period October 2017–March 2018 is about 1720 hours. It is determined from 40 hours operation time a week which were a several weeks off.*
2. *Every hardware, peripheral, and software has different frequency of failures. Once failed, it has any given downtime. The waiting and repairing time which are part of the downtime is considered to be*

assumed. Most of failures are treated as soon as possible, except for hardware and peripheralwhich need an outsourcing organisation involvement and necessary waiting time to do the maintenance tasks.

3. *Hardware and peripheraloperate in a paralel production line.*

Availability is the ability of an asset to perform its function as required. The previous figure 4 explains the relationship between the concepts of availability from mean time between failures (MTBF), mean downtime (MDT), mean waiting time (MWT) and mean time to repair (MTTR). Therefore, the equation of availability of the asset can be formulated as equation below (Labib, 2009).

$$Availability, A = \frac{MTBF}{MTBF+MTTR} \times 100\%$$

From the conditions which are given above, the availability of the machinery and major equipment in the Computer Laboratory of UniversitasPahlawanTuankuTambusai can be calculated as shown in table 2.

Table 2 Availability of the PC in Laboratory Facility

No.	Personel Computer	Frequency	Downtime	MDT	MTBF	MTTR	Availability
1	PC 01	0	0	0	0	0	100,00
2	PC 02	12	2280	190	8400	166	98,06
3	PC 03	41	1320	32	2460	33	98,68
4	PC 04	2	480	240	53100	240	99,55
5	PC 05	5	6600	1320	19320	1080	94,71
6	PC 06	6	1080	180	16980	186	98,92
7	PC 07	4	7680	1920	23880	1560	93,87
8	PC 08	3	540	180	34200	180	99,48
9	PC 09	9	11340	1260	10200	900	91,89
10	PC 10	6	8280	1380	15805	1020	93,94
11	PC 11	0	0	0	0	0	100,00
12	PC 12	2	240	120	51420	126	99,76
13	PC 13	1	2040	2040	101160	1560	98,48
14	PC 14	2	120	60	51480	78	99,85
15	PC 15	4	300	75	25680	84	99,67
16	PC 16	7	660	94	14640	96	99,35
17	PC 17	4	2880	720	25080	540	97,89
18	PC 18	2	2160	1080	50520	600	98,83
19	PC 19	1	180	180	102960	192	99,81
20	PC 20	0	0	0	0	0	100,00
21	PC 21	2	6720	3360	48240	3120	93,93
22	PC 22	0	0	0	0	0	100,00
23	PC 23	4	960	240	25500	246	99,04
24	PC 24	5	1260	252	20340	258	98,75
25	PC 25	0	0	0		0	100,00
26	PC 26	8	540	68	4050	72	98,25

Table 2 shows the availability of the har and major equipment for the period of February 2017 – February 2018. Total production operating times for these 6 months are expected as 1720 hours. Over the period, 130 breakdowns were recorded.

PC 09 highlighted has the longest downtime (11340minutes) with 9 times number of failures. It contributes as the most unreliable machine in the system with 91.89 % availability. It is followed by PC 07 with 93.87 % availability and PC 21 in the third place with 93.93 % availability. The PC 21 also is experienced the longest in term of mean time to repair (MTTR). Meanwhile, the PC 03 is experienced the most frequent number of failures with 41 times during the period. However, the asset only takes the ninth place of the most unreliable machine or equipment in the system with 98.69 % availability. It could be because the PC 03 has the shortest MTTR among the assets in the system.

4.2 DMG Model Analysis

The performance of maintenance organisation in this Computer Laboratory of UniversitasPahlawanTuankuTambusai could be improved by implementing the DMG model analysis. The analysis will provide the maintenance organisation to apply the appropriate maintenance policy and acivities for every PCwithin the Computer Laboratory facility.

• *Criteria Analysis*

The aim of this step is to establish Pareto analysis of two important criteria, downtime as the main concern of production and the number of failures as the main concern of assets management. The data of the two criteria for all machinery and the equipment is extremely needed for the DMG analysis. However, the downtime and the number of failure data can be substituted by data of mean time to repair (MTTR) and mean time between failures (MTBF) (Labib, 2004).

The data of the two criteria are then sorted and grouped into high, medium, and low Categories.Burhanuddin (2007) and Tahir et al (2008) mentioned that the groups can be determined by using simple interval as pointed out below, where "h" is the highest and "l" is the lowest.

- *High Boundary* = $h \leq High > h-(1/3h)$
- *Medium Boundary* = $h-(1/3h) \leq Medium > h-(2/3h)$
- *Low Boundary* = $h-(2/3h) \leq low \geq l$

In this DMG model analysis, the author proposes to use mean time to repair (MTTR) and mean time between failures (MTBF) data instead of the downtime and number of failures data. The reason is because the differences number of failures for the PC 03 (A3) in comparison with other production equipment is just too wide. It could lead to the difficulty in determining the interval of boundary. Since the downtime is proportional to MTTR value and the number of failures is inversely to MTBF value, the criteria evaluation will be as shown in table 3.

Table 3 Criteria Evaluation

Downtime			Frequency		
PC	MTTR	Criteria	PC	MTBF	Criteria
PC 21	3120	High	PC 19	102960	High
PC 13	1560	Medium	PC 13	101160	
PC 07	1560		PC 04	53100	
PC 05	1080		PC 14	51480	
PC 10	1020		PC 12	51420	
PC 09	900	Low	PC 18	50520	
PC 18	600		PC 21	48240	

PC 17	540		PC 08	34200	
PC 24	258		PC 15	25680	
PC 23	246		PC 23	25500	
PC 04	240		PC 17	25080	
PC 19	192		PC 07	23880	
PC 06	186		PC 24	20340	
PC 08	180		PC 05	19320	
PC 02	166		PC 06	16980	
PC 12	126		PC 10	15805	
PC 16	96		PC 16	14640	Medium
PC 15	84		PC 09	10200	
PC 14	78		PC 02	8400	
PC 26	72		PC 26	4050	Low
PC 03	33		PC 03	2460	

• *Decision Mapping*

Based on the criteria analysis proposed by Labib (1996), the aim of this step is to address both downtime and frequency criteria into two dimensional matrix as shown in table 4.

Table 4 Decision Making Grid Mapping

Decision Making Grid		Downtime		
		Low	**Medium**	**High**
Frequency	**Low**	OTF (PC 03,26)	FTM	CBM
	Medium	FTM (PC02,09,06,16)	FTM (PC10)	FTM
	High	SLU (PC04,08,12,14,15, 17,18,19,21,23,24)	FTM (PC 05,07,13)	DOM (PC 21)

• *DMG Model Suggestion*

The objective of the DMG model analysis is to implement appropriate maintenance policies and activities that will lead the movement of Personel Computer performance toward an improvement. In general, the decision making grid (DMG) mapping indicates that most of PCsare located in the lower triangle of the DMG matrix. As mentioned earlier in Figure 6, which means by implementing an adequate Total Productive Maintenance (TPM) concept in these software, hardwares and peripherals could lead to an availability improvement. Otherwise, in case of PC 03, PC 26, PC 10, PC 21, combination policies TPM with Reliability Centred Maintenance (RCM) concept will be more appropriate.

The following numbers are few maintenance strategies or actions recommended to be taken based on the DMG model analysis:

1. *Operate to Failure (OTF): this strategy is implemented to PC 03, PC 26. Since the downtime and frequency of failures of this equipment are low, the author recommends that the current maintenance strategy should be maintained and strictly followed.*
2. *Fixed Time Maintenance (FTM): this strategy is implemented to PCs which have the downtime and frequency of failures is almost at moderate cases. Preventive maintenance schedules should be applied. Fixed Time Maintenance, as mentioned earlier in Figure 7, is divided into easy tasks FTM and difficult tasks TPM. The recommendations proposed for every PCs which fall to FTM region in the DMG mapping as follow:*
   - *PC 02, PC 06, PC 09, PC 16 are located in the region between OTF and SLU. In this region, the question is about who will performed the maintenance tasks is the main concern. However, since it is near to SLU region, an upgrading the operator skill could be considered to be implemented.*
   - *PC 10 is fall into the FTM region in the midlle of OTF,SLU, CBM, dan DOM. Since it is categorised as medium task FTM and between CBM and TPM region, the adequate schedules of preventive maintenance should be established and Condition Based Monitoring (CBM) policy could be considered.*
   - *PC 05, PC 07, and PC 13 are located in the region between SLU and DOM. In this case, the contents of the preventive maintenance instructions need to be investigated and an expert advice is needed.*

3. *Skill levels upgrade (SLU): this strategy is implemented to PCs which indicates high frequency of failures for limited periods (low downtime). They are PC 04, PC 08, PC 12, PC 14, PC 15, PC 17, PC 18, PC 19, PC 21, PC 23, and PC 24. Since the downtime is low, it can be assumed that the maintenance tasks relatively are easy. It can be passed to operators/users after upgrading their skills level.*

4. *Design-Out Maintenance (DOM): this strategy should be implemented for PC 21. Since the rate of avalability still quite high, it means that there are part of equipment or component which needs to replace. Furthermore, only higher skill users are allowed to oparate this PC.*

5.1 Conclusion

This research proposes the Decision Making Grid (DMG) model analysis to determine the appropriate maintenance policy and activity to be implemented for all individual PC in Computer Laboratory. Started by availability analysis to determine performance of the PC which has unplanned breakdown records, and will be analysed then using the DMG model. The DMG analysis recommends TPM approach to be implemented for most PC in the facility excluding PC 10 and PC 21. In case of both PCs, combining RCM concept with TPM will be more appropriate.

Furthermore, the DMG analysis also suggests an upgrading operator/ user skills level for mostPCswhereare located in SLU region of DMG mapping. Meanwhile, the PC 10 is located in the FTM region between CBM, OTF, SLU and DOM. Since it is in the middle, combining Skill Level Upgrade (SLU) and Condition Based Monitoring (CBM) policy could be considered and recommended to establish an adequate preventive maintenance including the content, schedules, and who will perform the maintenance tasks. Finally, PC 21 which is located in DOM area needs to consider replacing some parts or componets rather than just applying the same maintenance strategies with PC 10.

5.2Future Work

In this research, the DMG model implementation provides decision analysis for strategic level and tactical level maintenance management in a conventional Computer Laboratory of UniversitasPahlawanTuankuTambusai. However, there are still many spaces used to develop a comprehensive maintenance optimisation model using the DMG technique on that area. Maintenance *cost analysis and maintenance resources control to determine periodic maintenance schedules should be taken into considerations for future work.*

Furthermore, the author suggests the Computer Laboratory of UniversitasPahlawanTuankuTambusai which still adopts old-fashioned maintenance system to use a Computerised Maintenance Management System (CMMS) with Decision Support System (DSS) application. Since the existing CMMSs software with support decision analysis in the market are expensive and limited, developing a CMMS application with the DMG analysis for Computer Laboratory of UniversitasPahlawanTuankuTambusai could be taken into consideration for the future work.

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