A decision analysis model for maintenance policy selection using a CMMS

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Keywords

Fuzzy logic, Analytical hierarchy process, Maintenance programmes

Abstract

In this paper, an investigation of the characteristics of computerised maintenance management systems (CMMSs) is carried out to highlight the need for them in industry and identify their current deficiencies. A proposed model provides a decision analysis capability that is often missing in existing CMMSs. The proposed model employs a hybrid of intelligent approaches. This hybrid system is analogous to the Holonic concept. The distinction between these two features is important. The rules function automatically. *Practical implications.* The main practical implication of this paper is the proposal of an intelligent model that can be linked to CMMSs to add value to data collected in the form of provision of decision support capabilities. A further implication is to identify the need for information to aid maintenance, followed by the provision of reasons for current deficiencies in existing off-the-shelf CMMSs.

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Introduction

In this paper, the author proposes to implement the holonic concept in maintenance systems. The main features of the holonic concept are fixed rules and flexible strategies. In this paper, the author will attempt to apply these concepts into the maintenance systems for manufacturing. Therefore, using a hybrid of a rule-base approach and the analytic hierarchy process (AHP) technique, the relationship and criteria of the proposed system will be analysed.

This paper is organised as follows. In the next section we discuss the characteristics of computerised maintenance management systems (CMMSs) highlighting the need for them and their current deficiencies. We then discuss holonic concepts with emphasis on applications in maintenance of manufacturing systems. Relationship analysis among criteria that are governing the proposed maintenance model will be presented in the following section followed by an industrial case study of the model's implementation. Finally, conclusions and directions for future research are presented.

Need for information to aid maintenance management

Several factors are driving the need for information to aid maintenance management. First, the amount of information available, even to quite modest organisations, continues to increase almost exponentially. What is more, there is an increasing requirement to have this data and information on hand and in real-time for decision-making. Secondly, data-life-time is diminishing as a result of the shop-floor realities, which are real-time in nature, and the rapid pace of change. The initiative now is to acquire data about individual machines, based upon real interactions rather than deduced behaviour from historical data. Finally, the way that data is being accessed has changed. The days of legacy maintenance systems of large batch reports, where the focus was on data throughput, are being replaced by dynamic, online queries, created on-the-fly, and with answers in seconds rather than days.

As in almost every sphere of organizational activity, modern computational facilities have offered dramatic scope for improved effectiveness and efficiency. Maintenance is one area in which computing has been applied, and CMMSs have

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existed, in one form or another, for several decades. The software has evolved from relatively simple mainframe planning of maintenance activity to Windows-based, multi-user systems that cover a multitude of maintenance functions. The capacity of CMMSs to handle vast quantities of data purposefully and rapidly has opened up new opportunities for maintenance, facilitating a more deliberate and considered approach to managing an organization's assets.

The CMMS is now a central component of many companies' maintenance departments, and it offers support on a variety of levels in the organizational hierarchy which are as follows:

- it can support condition based monitoring (CBM) of machines and assets, to offer insight into wear and imminent failures;
- it can track the movement of spare parts and requisition replacements when necessary;
- it allows operators to report faults faster, thus enabling maintenance staff to respond to problems more quickly;
- it can facilitate improvement in the communication between operations and maintenance personnel, and is influential in ameliorating the consistency of information passed between these two departments;
- it provides maintenance planners with historical information necessary for developing PM schedules;
- it provides maintenance managers with information in a form that allows for more effective control of their department's activities;
- it offers accountants information on machines to enable capital expenditure decisions to be taken; and
- it affords senior management a crucial insight into the state of asset healthcare within their organisation.

Indeed, the present author, Labib *et al.* (1998) has previously observed that ideally a CMMS is a means to achieving world-class maintenance, by offering a platform for decision analysis and thereby acting as a guide to management. CMMS packages are able to provide management with reports and statistics, detailing performance in key areas and highlighting problematic issues. Maintenance activities are consequently more visible and open to scrutiny. Managers can rapidly discover which policies work, which machines are causing problems, where overspend is taking place, and so on, thereby revealing information that can be used as the basis for the systematic management of maintenance. Thus, by tracking asset "health" in an organised and systematic manner, maintenance management can start to see how to improve the current state of affairs. However, the majority of CMMSs in the market suffer from serious drawbacks as will be shown in the following section.

Current deficiencies in existing off-the-shelf CMMSs

Most existing off-the-shelf software packages, especially CMMS and enterprise resource planning (ERP) systems, tend to be "black holes". This term is coined by the author as a description of systems greedy for data input that seldom provide any output in terms of decision support. Companies consume a significant amount of management and supervisory time compiling, interpreting and analysing the data captured within the CMMS. Companies then encounter difficulties analysing equipment performance trends and their causes as a result of inconsistency in the form of the data captured and the historical nature of certain elements of it. In short, companies tend to spend a vast amount of capital in acquisition of off-the-shelf systems for data collection and their added value to the business is questionable.

All CMMS systems offer data collection facilities; more expensive systems offer formalised modules for the analysis of maintenance data; the market leaders allow real time data logging and networked data sharing (Figure 1). Yet, despite the observations made above regarding the need for information to aid maintenance management, virtually all the commercially available CMMS software lacks any decision analysis support for management. Hence, as shown in Figure 1, a black hole exists in the row titled decision analysis because virtually no CMMS offers decision

Figure 1 Facilities offered by commercially available CMMS packages

	…	…	…	…
Data Collection	✓	✓	✓	✓
Data Analysis		✓	✓	✓
Real Time			✓	✓
Network				✓
Decision Analysis		A Black Hole		
Price Range	**£1k +**	**£10k +**	**£30k +**	**£40k +**

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support. This section has been reported in a paper titled; CMMSs: a black hole or a black box (Labib, 2003). It is included here in order to clarify the argument raised in this paper.

This lack of decision support is a definite problem, because the key to systematic and effective maintenance is managerial decision-taking that is appropriate to the particular circumstances of the machine, plant or organisation. This decision-making process is made all the more difficult if the CMMS package can only offer an analysis of recorded data. As an example when one inputs a certain preventive maintenance (PM) schedule to a CMMS, say to change the oil filter every month, the system will simply produce a monthly instruction to change the oil filter. In other words it is no more than a diary. A step towards decision support is to vary frequency of PMs depending on the combination of failure frequency and severity. A more intelligent feature would be to generate and to prioritize PMs according to modes of failure in a dynamic real-time environment. PMs are usually static and theoretical in the sense that they do not reflect shop floor realities. In addition, the PMs that are copied from machine manuals are not usually applicable because of the following:

(1) each machine works in a different environment and would therefore, need different PMs;
(2) machines designers often do not have the same experience of machines failures, and means of prevention, as those who operate and maintain them; and
(3) machine vendors may have a hidden agenda of maximizing spare parts replacements through frequent PMs.

A noticeable problem with current CMMS packages regards provision of decision support. Figure 2 shows how the use of CMMS for decision support lags significantly behind the more traditional applications of data acquisition, scheduling and work-order issuing. While many packages now offer inventory tracking, and some form of stock level monitoring, the reordering and inventory holding policies remain relatively simplistic and inefficient (Exton and Labib, 2002; Labiband Exton, 2001). Moreover, there is no mechanism to support managerial decision-making with regard to inventory policy, diagnostics or setting of adaptive and appropriate preventive maintenance schedules.

According to Boznos (1998) "The primary uses of CMMS appear to be as a storehouse for equipment information, as well as a planned maintenance and a work maintenance planning tool". The same author suggests that CMMSs appear to be used less often as a device for analysis and co-ordination and that "existing CMMS in manufacturing plants are still far from being regarded as successful in providing team based functions". He has surveyed CMMSs and also TPM and RCM concepts and the extent to which the two concepts are embedded in existing marketed CMMSs. He has then concluded that "it is worrying the fact that almost half of the companies are either in some degree dissatisfied or neutral with their CMMSs and that the responses indicated that manufacturing plants demand more user-friendly systems" (Boznos, 1998). This is a further proof of the existence of a "black-hole".

In addition, and to make matters worse, it appears that there is a new breed of CMMSs that are complicated and lack basic aspects of user-friendliness. Although they emphasise integration and logistics capabilities, they tend to ignore the fundamental reason for implementing CMMSs is to reduce breakdowns. These systems are difficult to handle by either production operators or maintenance engineers. They are more accounting and/or IT oriented rather than engineering-based. In short, they are Systems Against People that further promote the concept of black holes.

Results of an investigation of the existing reliability models and maintenance systems (EPSRC Grant No. GR/M35291) show that managers' lack of commitment to maintenance models has been attributed to a number of reasons (Shorrocks, 2000; Shorrocks and Labib, 2000).

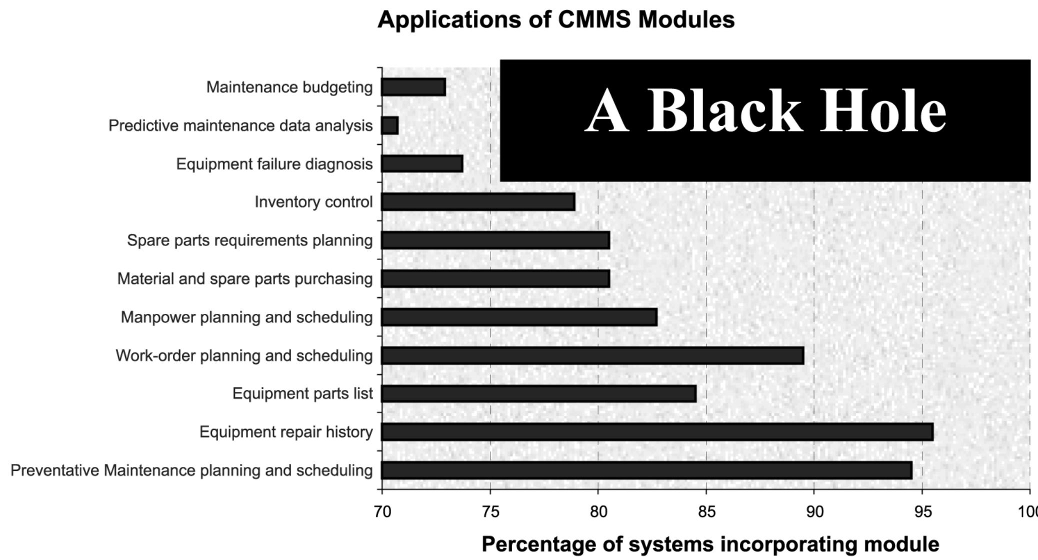
(1) managers are unaware of the various types of maintenance models;
(2) a full understanding of the various models and the appropriateness of these systems to companies are not available; and
(3) managers do not have confidence in mathematical models due to their complexities and the number of unrealistic assumptions they contain.

This correlates with recent surveys of existing maintenance models and optimisation techniques, Ben-Daya *et al.* (2001) and Sherwin (2000) have also noticed that models presented in their work have not been widely used in industry for several reasons such as:

(1) unavailability of data;
(2) lack of awareness about these models; and
(3) some of these models have restrictive assumptions.

Hence, theory and implementation of existing maintenance models are to a large extent disconnected. They concluded that there is a need to bridge the gap between theory and practice through intelligent optimisation systems (e.g. rule-based systems). They argue that the success of this type of research should be measured by its

Figure 2 Extent of CMMS module usage

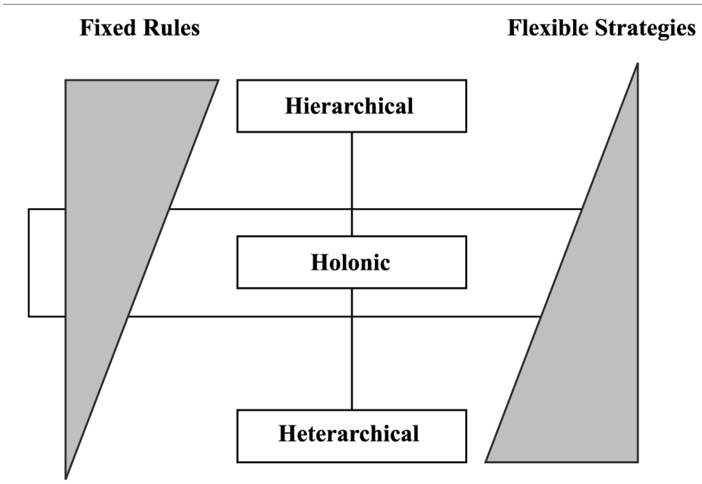


Source: From Swanson (1997)

relevance to practical situations and by its impact on the solution of real maintenance problems. The developed theory must be made accessible to practitioners through Information Technology tools. Efforts need to be made in the data capturing area to provide necessary data for such models. Obtaining useful reliability information from collected maintenance data requires effort. In the past, this has been referred to as data "mining," as if data can be extracted in its desired form if only it can be found.

In the next section we introduce the decision analysis model which embodies the Holonic concept (Figure 3). We then show how to implement such a model for decision support in maintenance systems.

Figure 3 Holonic form: combination of fixed rules and flexible strategies



Holonic systems

This concept is based on theory developed by Koestler (1989). He defined the word "holon" as a combination of the Greek word "holos" meaning "whole" and the suffix " – on", suggesting a particle or part (as in proton and electron, etc.), because of the following observations. First, he noticed that the complex adaptive systems will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not; the resulting complex system in the former case being hierarchic. Secondly, while Koestler was analysing hierarchy and stable intermediate forms in living organism and social organisation, he noticed that although – it is easy to identify sub-wholes or parts- "wholes" and "parts" in an absolute sense do not exist anywhere. This made Koestler propose the word "holon" to describe the hybrid nature of sub-wholes or parts in real-life systems; holons being simultaneously are self-contained wholes with respect to their subordinated parts, and dependent parts when regarded from the inverse direction.
The sub-wholes or holons are autonomous self-reliant units, which have a degree of independence and handle contingencies without asking higher authorities for instructions. Simultaneously, holons are subject to control form (multiple) higher authorities. The first property ensures that the holons are stable forms, which survive disturbances. The later property signifies that they are intermediate forms, which provide the proper functionality for the bigger whole (Christensen, 1994). Applying this concept to

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maintenance of manufacturing systems, a holonic control architecture is to comply with the concept of hierarchy in distributed systems.

In order to have an efficient function in the complex system, every holon has to behave according to fixed rules and flexible strategies. The fixed rules form a pattern of rules governing behaviour, which lends stability and cohesion between holons in the group (complex system), while flexible strategies allow the holon to be autonomous in frame of fixed rules. This flexible strategies enable the holon to determine how it operates and particular how it interacts with other holons in its environment (Bongaerts *et al.*, 2000).

Applying holonic concepts in manufacturing maintenance

The proposed holonic manufacturing maintenance model is based on the concept of effectiveness and adaptability. Mathematical models have been formulated for many typical situations. These models can be useful in answering questions such as "how much maintenance should be done on this machine?" How frequently should this part be replaced? How many spare should be kept in stock? How should the shutdown be scheduled? It is generally accepted that the vast majority of maintenance models are aimed at answering efficiency questions, i.e. questions of the form "How can this particular machine be operated more efficiently?" and not at effectiveness questions, like "Which machine should we improve and how?". The latter question is often the one in which practitioners are interested. From this perspective it is not surprising that practitioners are often dissatisfied if a model is directly applied to an isolated problem. This is precisely why in the integrated approach efficiency analysis as proposed by the author (do the things right) is preceded by effectiveness analysis (seeking to do the right thing). Hence, two techniques have been employed to illustrate the above-mentioned concepts, viz. the decision making grid (DMG) based on fuzzy logic and the AHP (Labib *et al.*, 1998). The proposed model is shown in Figure 4.

The DMG acts as a map on which the performances of the worst machines are located according to multiple criteria. The objective is to implement appropriate actions that will lead to the movement of machines towards an improved state with respect to these criteria. The criteria are determined through prioritisation based on the AHP approach. The AHP is also used to prioritise failure modes and fault details of components of critical machines within the scope of the actions recommended by the DMG.
The model is based on identification of criteria of importance such as downtime and frequency of failures. The DMG then proposes different maintenance policies based on the state in the grid. Each system in the grid is further analyzed in terms of prioritisations and characterisation of different failure types and main contributing components.

Maintenance policies

Maintenance policies can be broadly categorised as being either technology (systems, or engineering) oriented, human factors management oriented or monitoring and inspection oriented, reliability centered maintenance (RCM) – where reliability of machines is emphasised – failing in the first category, total productive maintenance (TPM) – a human factors based technique in which maintainability is emphasised – failing the second, and condition based maintenance (CBM) – in which availability based on inspection and follow-up is emphasised – failing in the third. The proposed approach here is different from the above in that it offers a decision map adaptive to the collected data, which suggests the appropriate use of RCM, TPM, and CBM.

The DMG through an industrial case study

This case study (Labib *et al.*, 1997) shows the application of the proposed model, and its effect on asset management performance, through the experience of a company seeking to achieve world-class status in asset management. the application has had the effect of reducing total downtime from an average of 800 to less than a 100 h per month as shown in Figure 5.

Company background and methodology

The manufacturing company has 130 machines, varying from robots, and machine centres, to manually operated assembly tables. notice that in this case study only two criteria are applied, viz. frequency and downtime. However, if more criteria were to be included, such as spare parts cost and scrap rate, the model would become multi-dimensional, with low, medium, and high ranges for each identified criterion. The

Figure 4 Holonic maintenance system

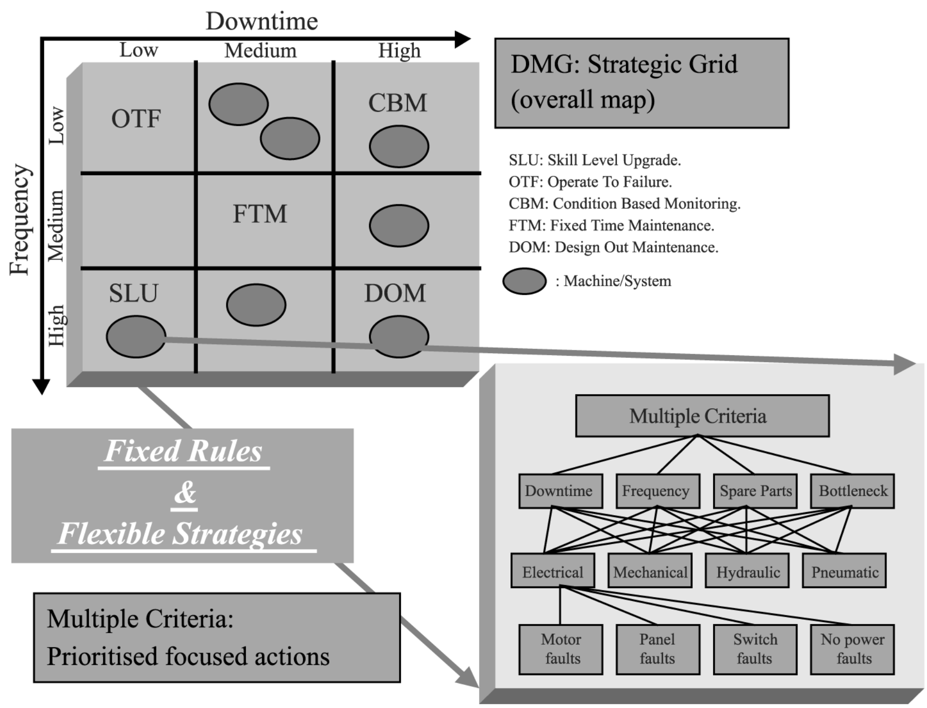
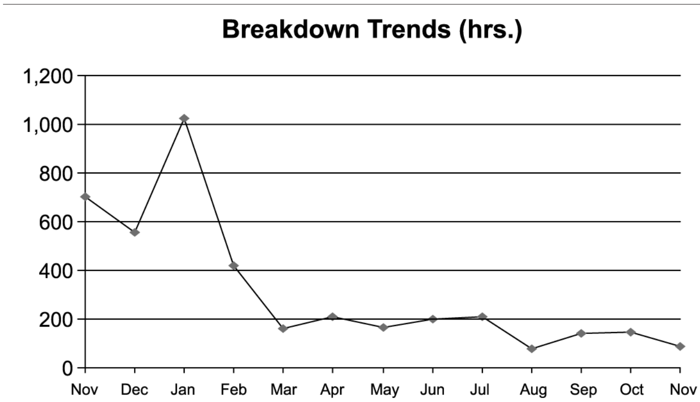


Figure 5 Total breakdown trends per month



methodology implemented in this case was to follow three steps which are as follows:
(1) criteria analysis;
(2) decision mapping; and
(3) decision support.

Step 1: criteria analysis
As indicated earlier the aim of this phase is to establish a Pareto analysis of two important criteria, viz. downtime (the main concern of production) and frequency of calls (the main concern of asset management). Notice that downtime and frequency can be substituted by mean time to repair (MTTR), and mean time between failures (MTBF), respectively. the objective of this phase is to assess how bad are the worst performing machines for a certain period of time, say one month. the worst performers as regards each criterion are sorted and placed into high, medium, and low sub-groups. These ranges are selected so that machines are distributed evenly among every criterion (Figure 6). in this particular case, the total number of machines (which include CNCs, robots, and machine centres) is 120.

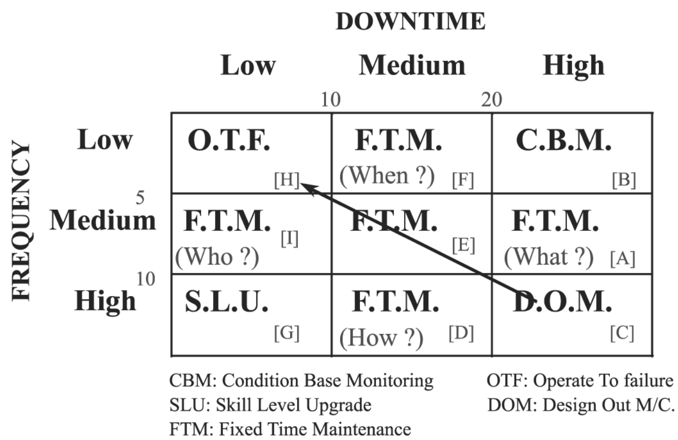
Step 2: decision mapping
The aim here is twofold; high, medium, and low groups are scaled and hence genuine worst machines in both criteria can be monitored on this grid. It also monitors the performance of different machines and suggests appropriate actions. The next step is to place the machines' performance on the DMG shown in Figure 7, and accordingly, to recommend asset management decisions to management. This grid acts as a map on which the performances of the worst machines are located according to multiple criteria. The objective is to implement appropriate actions that will lead to the movement of the grid location of the machines' performance towards the top-left section of low downtime, and low frequency. In the top-left region the action to implement, or the rule that applies, is operate to failure (OTF); In the bottom-left region it is skill level upgrade (SLU), because data collected from breakdowns – attended by maintenance engineers – indicates that a machine such as G has been visited many times (high frequency) for limited periods (low downtime). In other words maintaining this machine is a

Figure 6 Step 1: criteria analysis

Criteria:	Downtime		Frequency		
	Name	Downtime (hrs.)	Name	Frequency (No. off)	
HIGH	Machine [A]	30	Machine [G]	27	HIGH
HIGH	Machine [B]	20	Machine [C]	16	HIGH
HIGH	Machine [C]	20	Machine [D]	12	HIGH
MEDIUM	Machine [D]	17	Machine [A]	9	MEDIUM
MEDIUM	Machine [E]	16	Machine [I]	8	MEDIUM
MEDIUM	Machine [F]	12	Machine [E]	8	MEDIUM
LOW	Machine [G]	7	Machine [K]	8	MEDIUM
LOW	Machine [H]	6	Machine [F]	4	LOW
LOW	Machine [I]	6	Machine [B]	3	LOW
LOW	Machine [j]	4	Machine [H]	2	LOW
	Sum of Top 10	**138**	**Sum of Top 10**	**97**	
	Sum of All	**155**	**Sum of All**	**120**	
	Percentage	**89%**	**Percentage**	**81%**	

Criteria Evaluation

Figure 7 Step 2: decision mapping



relatively easy task that can be passed to operators after upgrading their skill levels.

Machines for which the performance is located in the top-right region, such as machine B, is a problematic one, in maintenance words a "killer". it does not breakdown often (low frequency), but when it does it usually presents a big problem that lasts for a long time (high downtime). In this case the appropriate action to take is to analyse the breakdown events and closely monitor its condition, i.e. condition base monitoring (CBM).

Location in the bottom-right region indicates a worst performing machine on both criteria; a machine that maintenance engineers are used to seeing not working rather than performing normal duty. A machine of this category, such as C, will need to be structurally modified and major design-out projects need to be considered, and hence the appropriate rule to implement will be design out maintenance (DOM).

If a medium downtime or a medium frequency is indicated the rule is to carry on with the preventive maintenance schedules. However, not all of the "medium" locations are the same. There are some that are near to the top left corner where the work is "easy" fixed time maintenance (FTM) – because the location is near to the OTF region – issues that need to be addressed include who will perform the work or when it will be carried out. For example, the performances of machine I is situated in the region between OTF and SLU and the question is about who will do the job – the operator, maintenance engineer, or sub-contractor. Also, the position on the grid of a machine such as F has been shifted from the OTF region due to its relatively higher downtime and hence the timing of tasks needs to be addressed.

Other preventive maintenance schedules need to be addressed in a different manner. The "difficult" FTM issues are the ones related to the contents of the job itself. It might be the case that the wrong problem is being solved or the right one is not being solved adequately. In this case machines such as A and D need to be investigated in terms of the contents of their preventive instructions and an expert advice is needed.

Notice that both machines J and K were located in one set but not the other as shown in Figure 6. This show that the two sets of top ten worst machines, in terms of frequency and downtime, need not be the same set of machines. Therefore, only common machines in both sets (genuine failures) will appear in the grid as shown in Figure 7. So, in Figure 7, both machines; J and K

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do not appear as they are outranking (one-off) events.

Step 3: multileveled decision support
Once the worst performing machines are identified and the appropriate action is suggested, it is now a case of identifying a focused action to be implemented. In other words, we need to move from the strategic systems level to the operational component level. Using the AHP, one can model a hierarchy of levels related to objectives, criteria, failure categories, failure details and failed components (Figure 8).

The AHP is a mathematical model, developed by Saaty (1980) that prioritises every element in the hierarchy relative to other elements in the same level. The prioritisation of each element is achieved with respect to all elements in the level above. Therefore, we obtain a global prioritised value for every element in the lowest level. In doing that we can then compare the prioritised fault details (level 4 in Figure 6), with PM signatures (keywords) related to the same machine. PMs can then be varied accordingly in a manner adaptive to shop floor realities.

The proposed holonic maintenance model as shown previously in Figure 4, combines both fixed rules and flexible strategies since machines are compared on a relative scale. The scale itself is adaptive to machine performance with respect to identified criteria of importance; that is frequency and downtime. Hence flexibility and holonic concepts are embedded in the proposed model.

Decision making grid based on FL rules

In practice, however, there can exist two cases where one needs to refine the model. The first case is when the performance makers of two machines are located near to each other on the grid but on different sides of a boundary between two policies. In this case we apply two different policies despite a minor performance difference between the two machines. The second case is when two such machines are on the extreme sides of a quadrant of a certain policy. In this case we apply the same policy despite the fact they are not near each other. For two such cases (Figure 9) we can apply the concept of FL where boundaries are smoothed and rules are applied simultaneously with varying weights.

In FL, one needs to identify membership functions for each controlling factor, in this case frequency and downtime as shown in Figures 10(a, b). A membership function defines a fuzzy set by mapping crisp inputs (crisp means "not fuzzy" in FL terminology) from its domain to degrees of membership (0,1). The scope/domain of the membership function is the range over which a membership function is mapped. Here the domain of the fuzzy set medium frequency is from

Figure 8 Step 3: decision support

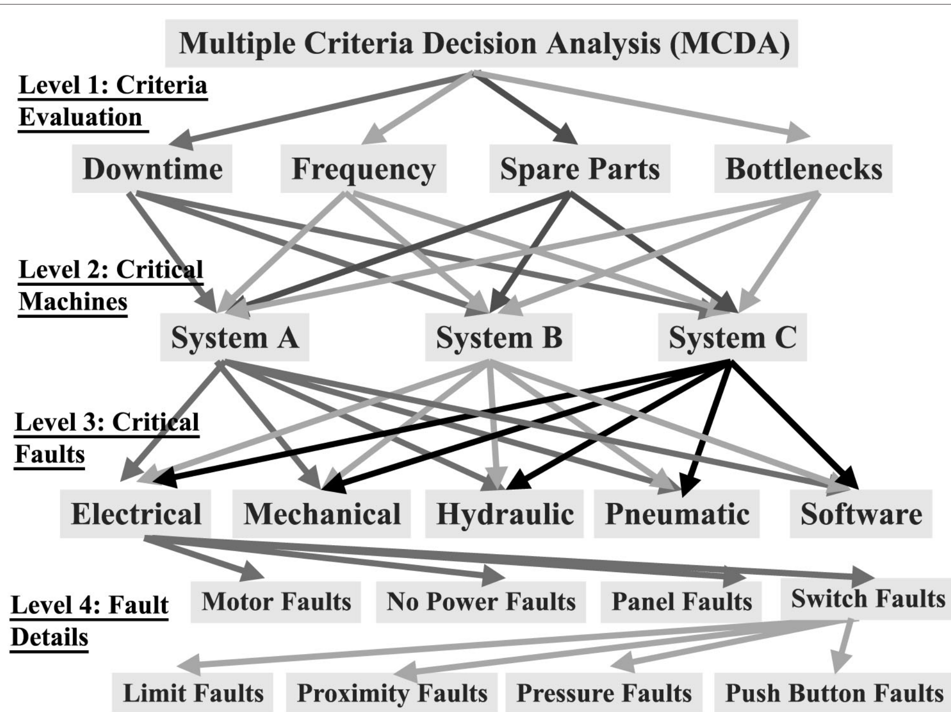

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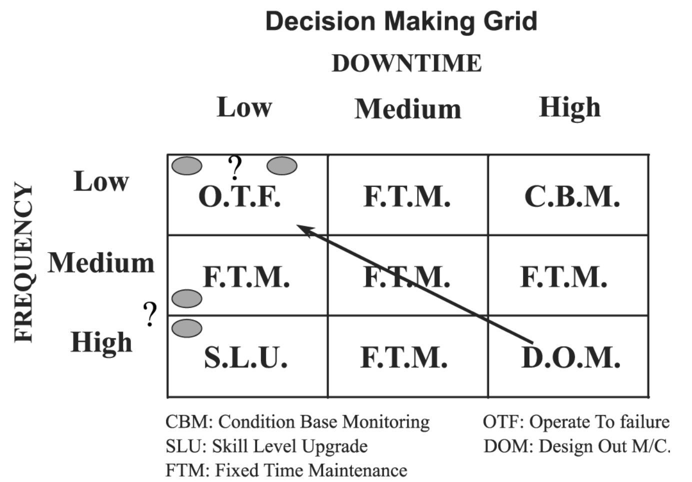
Figure 9 Special cases for the DMG model



10 to 40 and its scope is 30 (40-10), whereas the domain of the fuzzy set high downtime is from 300 to 500 and its scope is 200 (500-300) and so on. The basis for the ranges in Figures 10(a), (b) can be derived as estimates from the scale values of the ones obtained from the decision making grids over a period of time, an example could be the one shown in Figure 7.

The output strategies have a membership function and we have assumed a cost (or benefit) function that is linear and follows the relationship – DOM > CBM > SLU > FTM > OTF.

As shown in Figure 11(a). The rules are then constructed based on the DMG where there will be nine rules (Figure 11(b)), examples of which are as follows:

- if frequency is high and downtime is low then maintenance strategy is SLU; and
- if frequency is low and downtime is high then maintenance strategy is CBM.

The fuzzy decision surface is shown in Figure 12, from which, any combination of frequency and downtime (indicated on the x and y axes, respectively) one can determine the most appropriate strategy to follow (indicated on the z axis).

It can be noticed from Figure 13 that the relationship – DOM > CBM > SLU > FTM > OTF is maintained. As illustrated, for a 380 h downtime and a 12 times frequency, the suggested strategy is CBM. As mentioned above through the combination of frequency (say 12 times) and downtime (say 380 h) (indicated on the x and y axes, respectively) one can then determine the most appropriate strategy to follow (indicated on the z axis) which belongs to the CBM region as shown in Figure 12.

Discussion

The concept of the DMG was originally proposed by the author (Labib, 1996). It was then implemented in an automotive company based in the UK that has achieved a World-Class status in maintenance (Labib, 1998a) and has been extended to be used as a technique to deal with crisis management in an award winning paper (Labib, 1998b)[1]. Fernandez *et al.* (2003) developed and implemented a CMMS that used the DMG in its interface for a disk pad manufacturing company in the UK (Fernandez *et al.*, 2003).

The DMG could be used for practical continuous improvement. When machines in the top ten of the list of worst performers have been appropriately dealt with, others will move down the list and resources can be directed at these new offenders. If this practice is continued all machines will eventually be running optimally.

If problems have been chronic – i.e. regular, minor and usually neglected – some of them could be due to the incompetence of the user and SLU would be an appropriate solution. However, if machines tend towards RCM then the problems

Figure 10 Membership function of (a) frequency; and (b) downtime

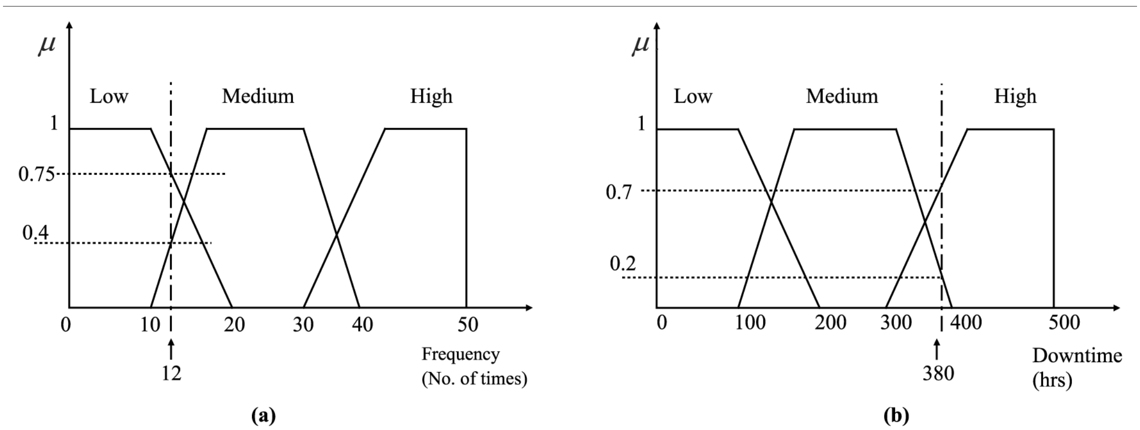


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Figure 11 (a) Output (strategies) membership function; and (b) the nine rules of the DMG

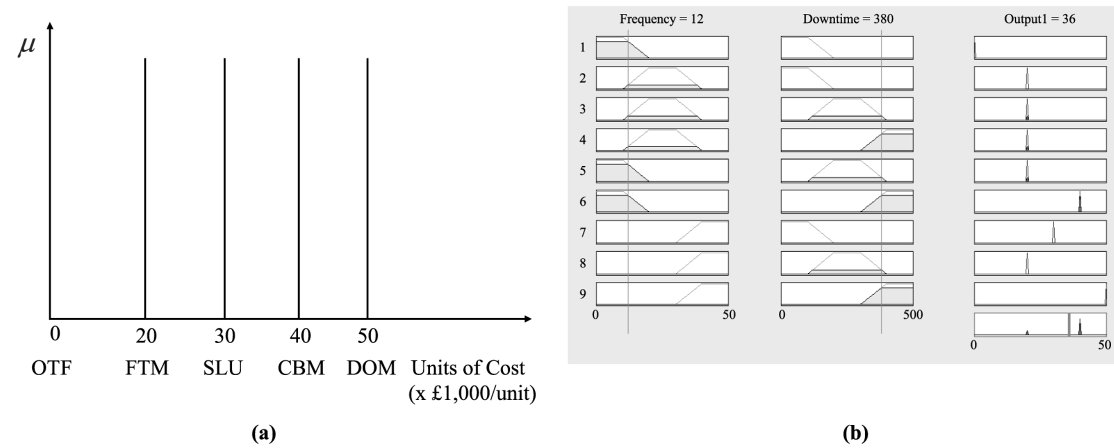
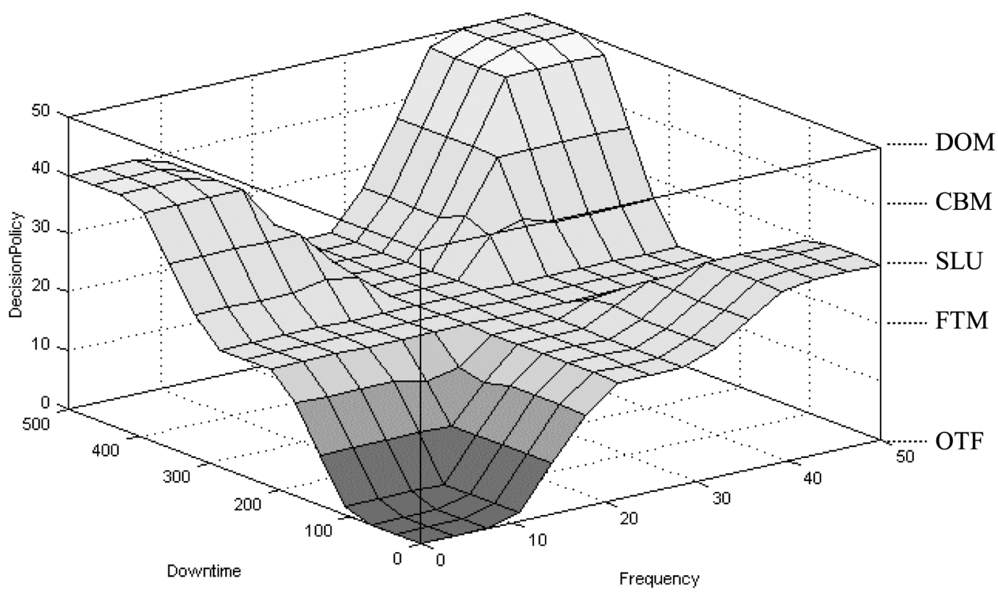


Figure 12 The fuzzy decision surface



are more sporadic and when they occur it could be catastrophic. Techniques such as failure mode and effect analysis (FMEA) and fault tree analysis (FTA) can help determine the cause of the problems and may help predict failures, thus allowing a prevention scheme to be devised.

Figure 14 shows when to apply TPM and RCM. TPM is appropriate at the SLU range since SLU of machine tool operators is a fundamental concept of TPM. RCM is applicable for machines exhibiting severe failures (high downtime and low frequency). Also CBM and FMEA will be ideal for such failures and hence an RCM policy (which require FMEA and, more often than not, indicates CBM as optimal) will be most applicable. 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.

In general the easy PM and FTM questions are "Who?", and "When?" (the efficiency questions). The more difficult ones are "What?" and "How?" (the effectiveness questions), as indicated in the Figure 15.

In practice maintenance strategies are based on the failure rate characteristics, i.e. constant or variable, failure impact and failure rate trend. The DMG takes into account the failure rate, its impact and its trend for recommending and particular maintenance strategy. The failure rate is taken into consideration as the frequency axis. The frequency can therefore be substituted with the mean time between failures (MTBF). The definition of MTBF is the average operating time between two

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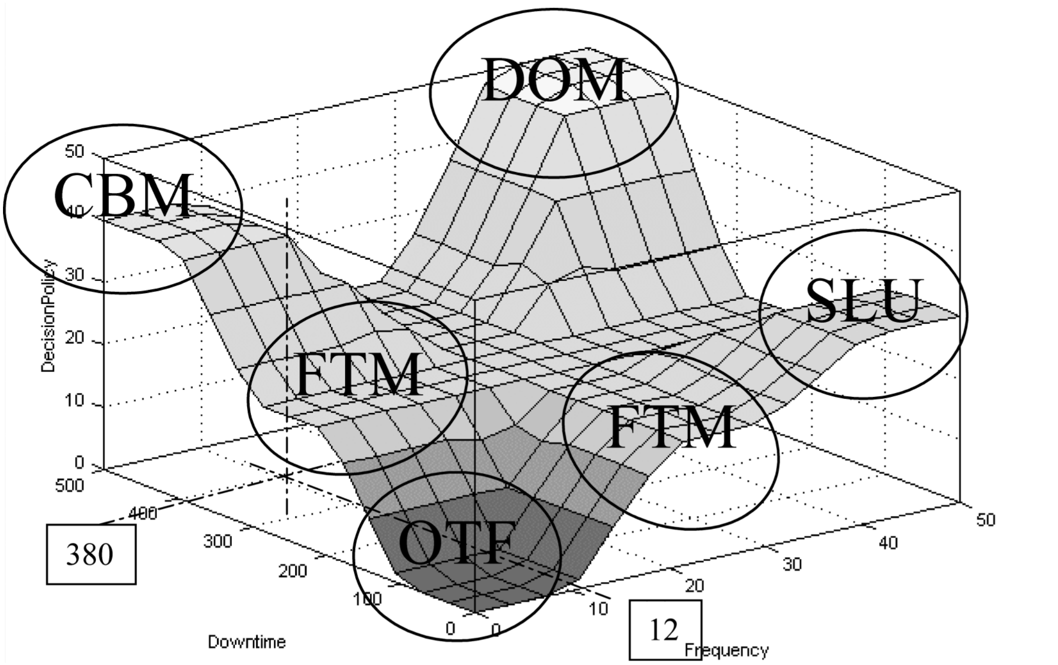

Figure 13 The fuzzy decision surface showing the regions of different strategies

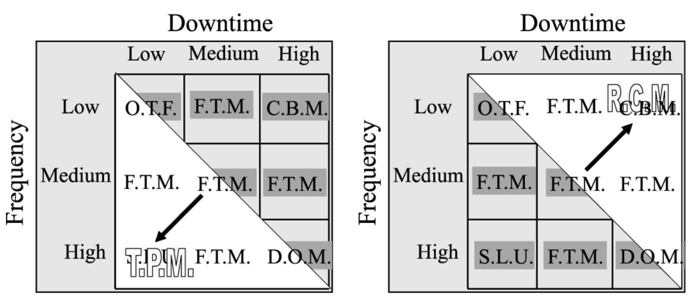

Figure 14 When to apply RCM and TPM in the DMG

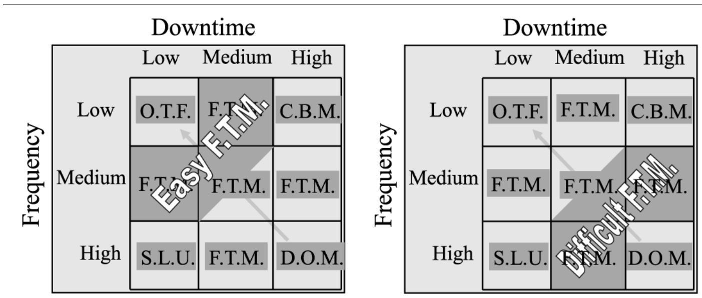

Figure 15 Parts of PM schedules that need to be addressed in the DMG

subsequent failures. It is a measure of how reliable a system is and thus the aim is to maximise it. It is affected by number of failures, and therefore could be substituted by frequency in the DMG but in a decreasing direction.

The failure impact is captured in the downtime axis. It can also be substituted with mean time to repair (MTTR). This is due to the fact that the definition of MTTR is the average time it takes to return a failed system to its initial operating state. This value needs to be minimised. Therefore, this is equivalent to downtime in the DMG.

As for the trend, the proposed model relies on relative comparison of plants in contrast with other classic models such as Weibull that relies on a large amount of data for a particular failure mode in order to study the trend. In other words, the DMG compares machines relatively, whereas Weibull looks at each machine in terms of its past and there is no relative comparison with other systems. The basic assumption in Weibull is that a system suffers from one type mode of failure, otherwise failure modes may compete and the value of β is the resultant. This is a major constraint with Weibull. On the other hand, the basic assumption in the DMG is that machines are comparable, therefore, it applies only to batch manufacturing but not to compare, for example, a transfer line with a small machine. The DMG addresses issues related to many maintenance decision policies (for, e.g. DOM. CBM, FTM, etc.), whereas, the Weibull analysis addresses trade-off decision policies between replace and repair decision-making based on the value of β.

Conclusion

The main idea is based on the fact that the "black hole" or missing functionality in conventional CMMSs is the lack of intelligent decision analysis tools. A model has been proposed based on

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combining the AHP with FL control to render a "Decision Making Grid". This combination provides features of both fixed rules and flexible strategies.

The grid supports the making of decisions about how assets should be maintained – whether, for example, to run to failure, to upgrade operator skills, to maintain on a fixed time basis, or to design out the causes of failures. It then gives a prioritised focus within the scope of the suggested policy in order to dynamically adapt maintenance plans through the performance, in a consistent manner, of trade-off comparisons.

The basic data requirements are simply the asset register, a fault counter, a timer, and a hierarchical fault tree as follows:

- the asset register identifies the different machines and plants, the fault counter records the frequency of occurrence of faults (the first parameter used by the DMG, and which could be obtained from any CMMS or by using Programmable Logic Controllers (PLCs);
- the fault timer records downtime (the second parameter used by the DMG and likewise obtainable from any CMMS or by using PLCs); and
- the fault tree in order to establish the hierarchical level of faults (which is important for the AHP model where the combination of structured fault codes and flexible description needs to be considered).

These basic requirements are usually easy to find in existing CMMSs. It is therefore proposed that such a model could be attached as an intelligent module to existing CMMSs – thus filling a black hole with an intelligent black box that adds value to the business.

Note

1 Received the "Highly Commended Award 1999" from the Literati Club, MCB Press (a publisher of 140 journals), for a paper entitled "A Logistics Approach to Managing the Millennium Information Systems Problem" (Labib, 1998b), *Journal of Logistics Information Management*, MCB Press, 1998.

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Further reading

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