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Next Generation Maintenance Systems (NGMS): Emerging Educational and Training Needs to support An Adaptive Approach To Maintenance Planning And Improve Decision Support

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ABSTRACT
The paper will first outline current state of maintenance systems, moving on to show some of the benefits that can result from the application of computerised maintenance management systems (CMMS). This is followed by demonstration of evidence of black-holes. Finally, a black-box: A case study is presented.

Unmet needs in responsive maintenance will be highlighted followed by research & development questions. Key Features of NGMS will be outlined and example of some approaches will be highlighted.

Finally, we present a summary of how development of related training material in Maintenance Management can/will contribute to addressing the issues raised.

KEYWORDS
Maintenance, Educational needs, CMMS

FULL PAPER

1. Maintenance and Asset Management - definition and importance:

Maintenance has many definitions. One comprehensive definition is:

> ‘the **management, control, execution** and **quality** of those activities which will ensure that **optimum levels of availability** and **overall performance** of plant are achieved, in order to meet **business objectives**..'

The key words are in bold and note that the totality of design activity for the whole product and process life cycle is assumed. It is also worth noting that the definition implies that maintenance is a managerial and strategic activity and hence the term Asset Management is now often used instead.

The importance of maintenance (or asset management) can be signified by the following argument. The revenue of any company can be improved by any of the following alternatives:

- Setting higher prices on products: only valid if the company is in a monopolised market. Verdict: Good for the short term, bad for the long term as customers will search for other vendors.
- Reduction of production and maintenance costs. Only valid if these costs are not adding value to the business. An analogy could be instead of trimming the tummy of fat person one gets to cut the legs or arms in an effort to reduce weight!! Verdict: Good for the short term, bad for the long term if cost cutting affects vital activities such as training and quality related expenditures.
- Increased productivity. Verdict: Good for both the short and long terms.
- High quality products. Verdict: Good for both the short and long terms.

Maintenance cannot influence the first two of these but it's instrumental in the last two.

2. Current State of Maintenance Systems.

Morden computational facilities have offered dramatic scope for improved effectiveness and efficiency. Maintenance is one area in which computing has been applied, and Computerised Maintenance Management Systems (CMMS) have 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 CMMS 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 organisation's assets.

Some of the benefits that can result from the application of computerised maintenance management systems (CMMS) are:

1. Resource Control: Tighter control of resources (maintenance personnel, spare parts, equipment, etc).

2. Cost Management: Better cost management and audibility.

3. Scheduling: Ability to schedule complex, fast moving, workloads.

4. Integration: Integration with other business systems.

5. Reduction of Breakdowns: Improve reliability of physical assets through the application of an effective maintenance programme.

Perhaps, the most important one is item 5 above. This is the aim of the maintenance function and the rest are 'nice' objectives (or by-products). Some system developers and vendors as well as some users often lose focus and compromise reduction of breakdowns in order to maintain standardisation and integration objectives. This has lead to the fact that the majority of CMMS in the market suffer from serious drawbacks as will be shown in the following section.

2.1. Evidence of black-holes

Most existing off-the-shelf software packages, especially Computerised Maintenance Management Systems (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 of-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 [see Table 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 indicated in Table 1, a black hole exists in the row titled Decision Analysis because virtually no CMMS offers decision support. This section has been reported in a paper titled; Computerised Maintenance Management Systems (CMMS): A black hole or a black box (Labib, 2003). It is included here in order to clarify the argument raised in this paper.

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

Table 1 Facilities offered by commercially available CMMS packages

This lack of decision analysis 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 PM depending on the combination of failure frequency and severity. A more intelligent feature would be to generate and to prioritize PM according to modes of failure in a dynamic real-time environment. PM is usually static and theoretical in the sense that they do not reflect shop floor realities.

In addition, the PM that is copied from machine manuals is not usually applicable because:

(a) each machine works in a different environment and would therefore need different PM,

(b) machines designers often do not have the same experience of machines failures, and means of prevention, as those who operate and maintain them, and.

(c) machine vendors may have a hidden agenda of maximizing spare parts replacements through frequent PM.

A noticeable problem with current CMMS packages is the lack provision of decision analysis support. Figure 1 illustrates 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 (See Exton & Labib (2001), and Labib and Exton (2002) for more details). 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.

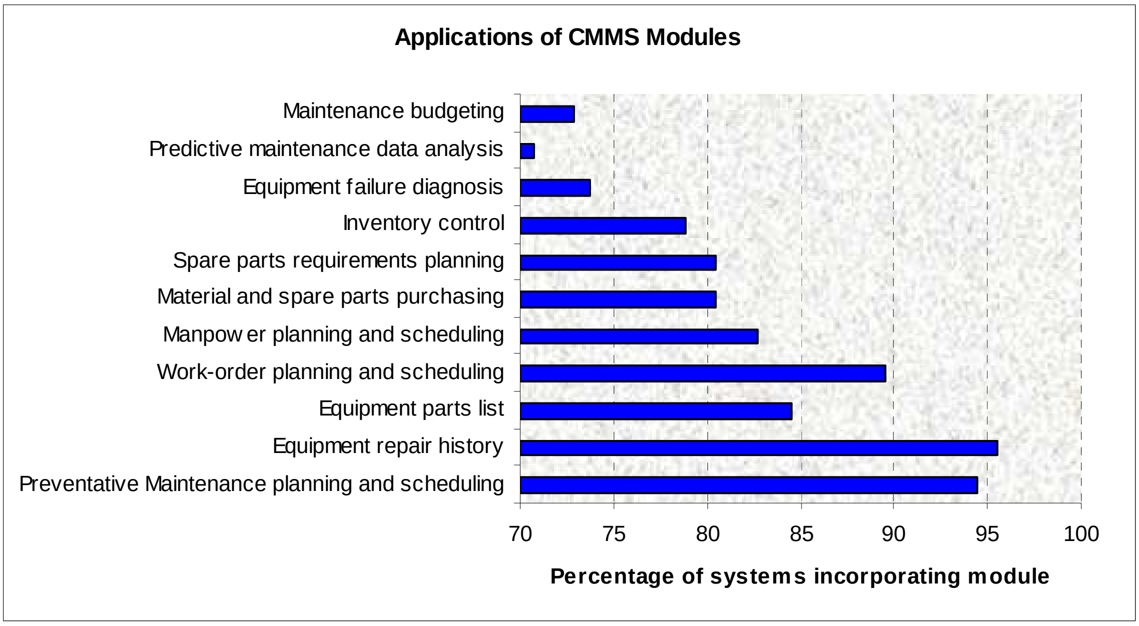

Figure 1 Extent of CMMS module usage (from Swanson, 1997)

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 CMMS appears to be used less often as a device for analysis and co-ordination and that "e*xisting CMMS in manufacturing plants are still far from being regarded as successful in providing team based functions*". He has surveyed CMMS and also TPM and RCM concepts and the extent to which the two concepts are embedded in existing marketed CMMS. He has concluded that:

"it is worrying the fact that almost half of the companies are either in some degree dissatisfied or neutral with their CMMS 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 CMMS 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 CMMS is to reduce breakdowns. These systems are difficult to handle by either production operators or maintenance engineers. They are more accounting and/or information technology 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 and Labib, 2000), and (Shorrocks, 2000):

(i) Managers are unaware of the various types of maintenance models,

(ii) A full understanding of the various models and the appropriateness of these systems to companies are not available, and

(iii) 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 etal (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:

(i) Unavailability of data,

(ii) Lack of awareness about these models, and

(iii) 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 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 highlight unmet needs in maintenance systems.

3. Unmet needs in responsive maintenance.

According to Jay Lee, Director of NSF Industry/University Cooperative Research Center on Intelligent Maintenance Systems (IMS) at the University of Cincinnati, unmet needs in responsive maintenance can be categorized into the following:

1. Machine Intelligence: Intelligent monitoring, predict and prevent, and compensation, reconfiguration for sustainability (self-maintenance).

2. Operations Intelligence: Prioritize, optimize, and responsive maintenance scheduling for reconfiguration needs.

3. Synchronization Intelligence: Autonomous Information Flow from Market Demand To Factory Asset Utilization.

Hence, we can conclude that research and development questions concerning next generation maintenance systems are:

1. How to adapt PM schedules to cope dynamically with shop-floor reality?

2. How to feed back information and knowledge gathered in maintenance to the designers of the process?

3. How to link maintenance policies to corporate strategy and objectives?

4. How to synchronise production scheduling based on maintenance performance?

4. Further Discussion:

Based on The key features for next generation maintenance systems are:

1. Self-Reconfiguration.

2. Self-Maintenance, and Self-Healing.

3. Data to Information to Decisions.

4. Off-line to On-Line to Real-time.

5. Learn and Grow.

6. Diagnostics to Prognostics.

According to Charles Darwin:, "*It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change*". Therefore, Next Generation Maintenance Systems will have to be responsive to change otherwise they will follow the same fate as Dinosaurs who were strong and probably intelligent but perhaps not responsive.

5. A summary of how the MSc in Maintenance Management at Glasgow Caledonian University can/will contribute to the addressing the issues raised:

The author has been involved in teaching the MSc in Maintenance Management at Glasgow Caledonian University in the UK, The MSc in Maintenance Engineering at University of Manchester, and was external examiner for the MSc in Asset Management at Robert Gordon University in Aberdeen. These Programmes are designed in such a way to address the existence of a considerable gap between the required skills which are essential to maximise the potential benefits from these advanced technologies in the area of maintenance and asset management and the skills which currently exist within the maintenance sections of most industries.

In addition, he has taught maintenance modules in the USA. With this experience he is in a good position to assess the orientation of those Programmes, where the emphasis is on developing and nurturing skills and utilization of advanced technologies. Although the Programmes already address some of the issues related to next generation maintenance systems, there is still room for considering other issues such as:

- Emphasis on CMMS and ERP systems in the market; their use, and limitations.
- Design awareness in maintenance and design for maintainability.
- Learning from failures across different industries and disciplines.
- Emphasis on prognostics rather than diagnostics.
- E-maintenance and remote maintenance including self-powered sensors.

These are just ideas that will help to enhance an already excellent Programmes.

CONCLUSIONS

In this paper we have outlined current state of maintenance systems, and then presented some of the benefits that can result from the application of computerised maintenance management systems (CMMS). Unmet needs in responsive maintenance were highlighted followed by research & development questions. Key Features of NGMS were outlined and examples of some approaches were highlighted.
Finally, we presented a summary of how development of related training material in Maintenance Management can/will contribute to addressing the issues raised.

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