Building Maintenance Optimisation towards the Future of Building Information Model BIM

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1. Building maintenance is acknowledged as an important area that is worthy of study. It is broadly appreciated that the cost of maintenance of a building over its life can be much higher than its initial construction cost. Evans et al [1] study of the long term costs of owing and using buildings suggested a ratio of 1:5:200 relating the initial cost of the building to that of maintenance and operations respectively. Weather this ratio exaggerates the maintenance cost that can be open for debate, but maintenance cost over the life of the asset depends on the type of building and its use. For example in a study of post offices in Japan based on using life Cycle cash flow, the data suggests much lower ratio [2]. The ratio of initial cost to the cost of repair and improvement and to operating cost (utilities and maintenance) of post offices increases from 1: 0.21: 0.55 to 1: 0.65: 1.11 to 1: 1.28: 2.22 for 20, 40 and 60 years old buildings respectively. It is important to note the different terms used by Minami [2] e.g. they refer to maintenance cost as those relating to equipment maintenance, cleaning, security and refuse disposal costs. While this ratio is much lower than that suggested by Evans et al [1] it remains highly significant.

Irrespective of its cost, building maintenance is essential to maintain its functionality. But according to Barbour Index [3] the estimated market for Maintenance, Repair and Improvement (MRI) is £28bn compared with £10bn for new build. Wood [4] presents brief introduction to the recent history of building maintenance in the UK. He discusses the public policy with regard to building construction and maintenance from the focus on reconstruction following WWII, the slum clearance, introduction of building regulations, the modernisation of slums to the privatisation of council houses and the introduction of the Private Finance Initiative (PFI) and the Public/Private Partnerships to organise involvement of the private sector in the public sector construction work that was previously carried out by councils.

The first aim of this paper is to present an analysis of both the modern maintenance advances and the building maintenance research at presented with the gaps between them are identified. The paper then explores how Building Information Modelling (BIM) can be used to support building maintenance given the possible interaction between BIM, Computer Aided Facility Management (CAFM) and Computerised Maintenance Management Systems (CMMS) software. The paper is concluded with a proposed building maintenance framework.

2. Asset Management: The State Of The Art

Maintenance is an important part of operations management of any organisation. In industry, plant maintenance represents the focus of such activities. Its objective is generally acknowledged as being to maintain the condition of plant/ equipment at a state that allows delivery of its functions effectively and efficiently. Apart from industry, other types of organisations also have interests in maintenance of its assets including equipment used, buildings and its contents e.g. air conditioning and lefts.

Generally speaking and until the 1970s, maintenance was viewed as an area that no one wishes to get involved in. Instead, there was a tendency for association with production that produces goods or services that can make positive contribution to the organisation. In fact maintenance was thought of as the last uncontrolled area in the majority of business and a bastion of inefficiency [5].

In the past three decades organisations recognised the importance of maintenance management and researchers developed a huge body of knowledge in this area that ranges from the development of maintenance concepts to the specific management techniques and focus on case studies.

The structure of the Complex System Maintenance Handbook (Kobbacy and Murthy [6]) suggests that one can classify research in this area, excluding case studies, into four main areas: concepts and approaches, methods and technique, problem specific models and management. There is a substantial body of knowledge accumulated in each of these areas. More details are shown later in Figure (1).

3. Building Maintenance Research

Little attention was given to building maintenance management and planning until the 1960s. From the mid-1960s studies started to emerge in this area. Examination of two books published in the 1970s on building maintenance reveals the areas of interest and indeed the significant advances achieved by that time. The book on Building Maintenance Management by Lee [7] shows appreciation of the complexity of this area and its social and economic importance and the usefulness of utilising management techniques. The chapter on planning shows appreciation of the increasing cost resulting from the delay in undertaking maintenance actions and hence the importance of inspection and indeed the scheduling and the contingency (planned/ preventive) maintenance. The edited book on Developments in Building Maintenance-1[8] reveals the substantial advancements in this area and the emerging topics that remain to be of current research interest to date. Examples cover the decisions models and statistical aids in maintenance management. Techniques discussed include discounting, cost benefit analysis, mathematical programming and indeed the early models that were developed to optimise maintenance activities e.g. determining optimal inspection activities based on the pioneering work of Jardine [9] which continues to be reprinted to date.

4. The Gap between Modern Maintenance Advances and Building Maintenance Research

Figure (1) shows the areas of maintenance research according to the classification of Kobbacy and Murthy [6]. A review of the method and approaches developed in the maintenance domain which are typically applied in plant maintenance have identified the methods which are either not been applied or its potential has not been fully explored in building maintenance.

It is important to indicate that many of these methods and techniques while may have not been directly applied in building maintenance situations they are applicable to mechanical and electrical equipment that are used in buildings including lifts, air conditioning systems, water pumps etc. Examples of these techniques include conditions based maintenance, preventive maintenance, reliability predictions and accelerated testing etc. These equipment can typically be grouped under a broad building element namely

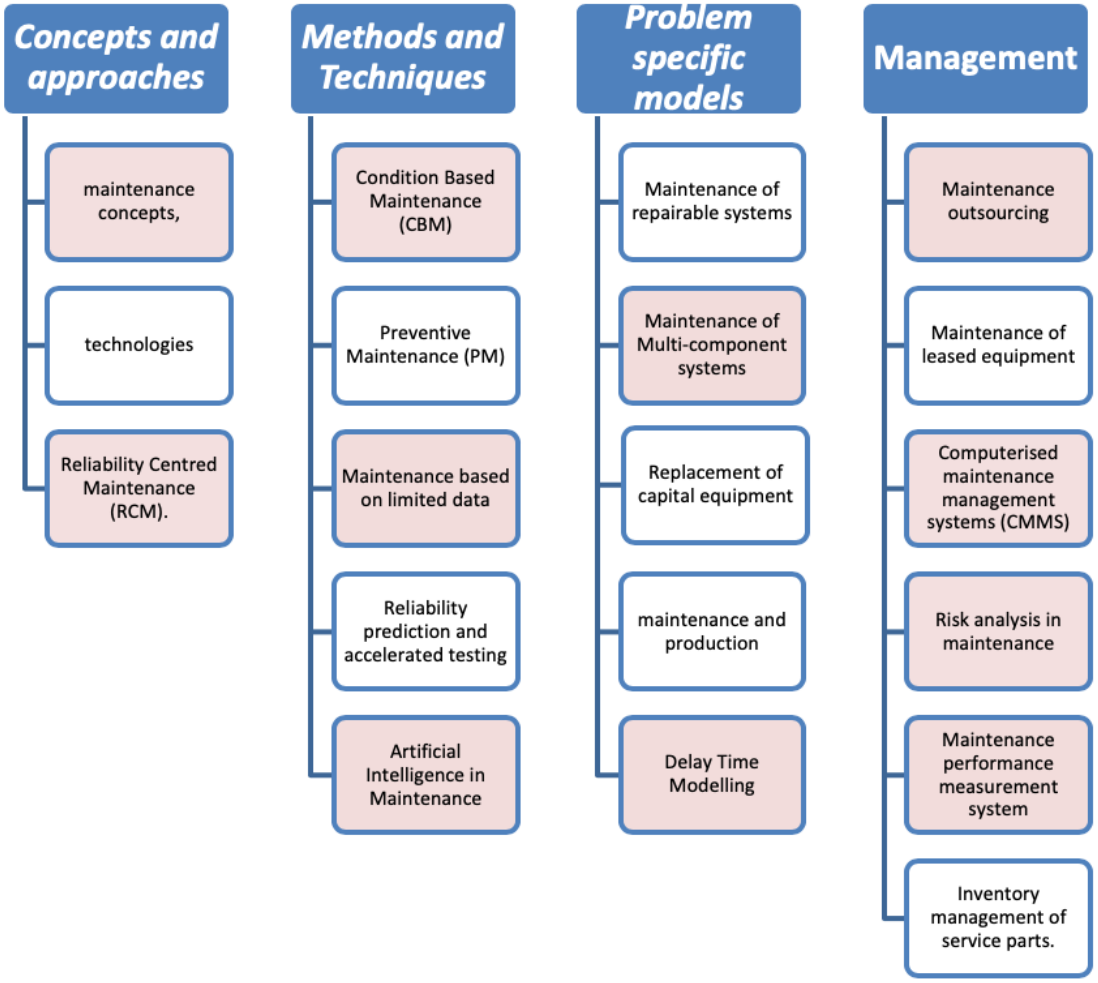
"services".

However building maintenance goes well beyond services. For example Elharam et al [10] identifies 11 building elements e.g. floor boards, windows, plaster, walls and doors. Our discussion below will focus on these building elements.

From the previous discussion one can identify the areas that are not explored fully in building maintenance and which have good potential in improving building maintenance. Broadly speaking these areas, which are hatched in Fig 1, include:

1. **Maintenance concepts.**
2. **RCM**
3. **Condition based maintenance.**
4. **Maintenance based on limited data.**
5. **Artificial Intelligence in maintenance.**
6. **Maintenance of multi-component systems**
7. **Delay time modelling.**
8. **Maintenance outsourcing**
9. **Computerised maintenance management systems (CMMS).**
10. **Risk assessment.**
11. **Maintenance performance measurements system**

Fig (1) The state of the art and gaps in building maintenance (hatched area indicates potential area of



development in building maintenance).

Therefore there is an obvious need to develop a building maintenance concept that guide the strategy of planning and managing building maintenance. An attempt is presented later in this paper. There is also a need to develop more work on the systematic application of RCM in this area.

In the area of methods and techniques the authors believe that a significant benefit can be gained from expanding CBM and the promising area of artificial intelligence techniques. Utilising the most promising statistical techniques on using limited data can be most useful in overcoming typical situations where data are scarce.

Given the complexity and interdependence of building elements it is obvious that utilising the powerful multi-component techniques in optimising building maintenance can be most useful. The same applies to the Delay Time modelling techniques, which were originally developed in the context of building maintenance. These techniques are particularly useful in timing the maintenance action to avoid undesirable and costly failures.

The development and application of maintenance performance measurement systems are essential to assess and develop effective and efficient maintenance policies. Exploring the benefits of maintenance outsourcing is another area that can help in achieving effective maintenance at lower costs. The use of CMMS will be discussed in the next section given the current interest and future expansion in using BIM.

5. Maintenance and Building Information Modelling (BIM)

Building Information Models or BIM was coined in the early years of the 21st Century. There are many definitions for BIM, but essentially it is a digital representation of the physical and functional characteristics of a facility [11]. BIM covers all stages of a building from design and construction to operations and maintenance.

It is expected that maintenance data in BIM models will build-up over the coming few years with the use of BIM which can potentially help more effective building operations and maintenance. The availability of such data will also lead to better managed buildings by reducing both energy use and waste. It is important to start understanding how such information will be used in maintenance management and indeed how the information in BIM can be used to project the maintenance requirements as early as the design phase. In other words the availability of this integrated system will lead to consideration of maintenance requirements at the design stage and hence maintenance cost will influence building design. Furthermore BIM will provide appreciation of maintenance requirements from the design stage. Large organisations now look primarily at facility performance rather than the physical structure [11]. For example the USA General Services Administration (GSA) has recently awarded contract to design, install and maintain major power facility.

5.1 BIM, CAFM and CMMS

These are 3 different categories of computerised systems that can help achieve effective building maintenance; Building Information Model (BIM), Computer Aided Facility Management (CAFM) and Computerised Maintenance Management systems (CMMS). The scope of BIM is broader than that of CAFM which automat many of the FM functions and results in cost savings and improved utilization of assets throughout the entire lifecycle. In particular, CAFM provide and maintain information on floor plans, space

utilization, energy consumption and equipment location [11]. CAFM scope is wider than that of the more maintenance specific software CMMS which is a computer software developed to provide support to maintenance managers in planning, management, and administration of the maintenance function with a view to improve its effectiveness. Each type of these software have a role in building maintenance and indeed BIM can be viewed as enabler to both CAFM and CMMS by providing understanding of the facility design and operation, its maintenance requirements and much needed data accumulated while operation.

Integrated CMMSs became the theme for recent development e.g. with asset management systems using costs, production quality, efficiency and facility condition in making decisions about productive and proactive maintenance strategies. Artificial Intelligence (AI) has been identified as a tool to achieve this integration. In a similar manner one would expect the integration of BIM, CAFM and CMMS leading to a more efficient management of buildings throughout its like cycle.

Figure (2) represents the possible interaction between the 3 types of software in supporting the building maintenance and indeed the wider aspects of facility management and other stages of building lifecycle. For example the decision support offered by CMMS can lead to better facility management. It is not surprising, therefore, that some commercial software are classified as both CAFA and CMMS.

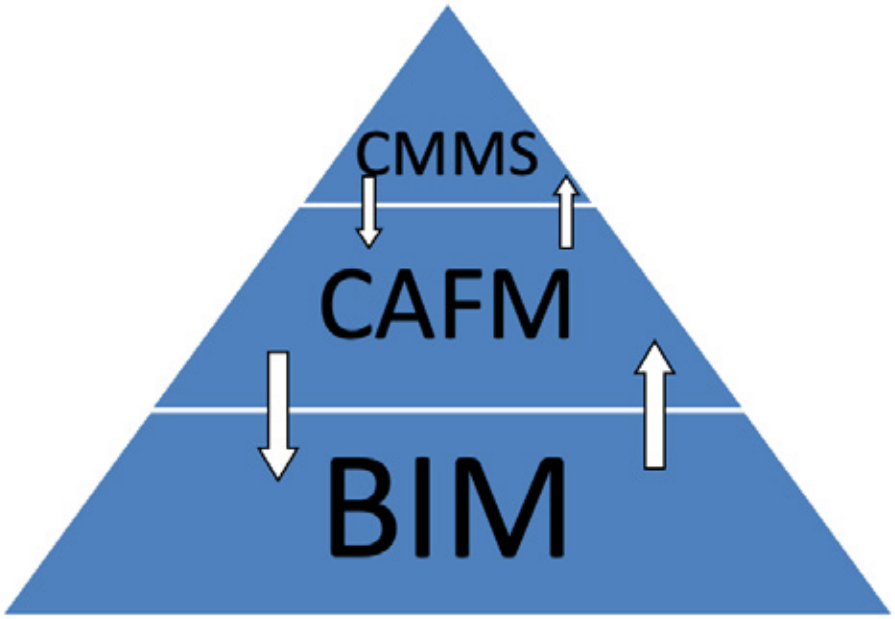


Fig (2) Integration of building management tools; BIM, CAFM and CMMS

6. CONCLUSIONS

This paper is concerned with the optimisation of building maintenance. An analysis of the methods and approaches developed in maintenance and building research reveals significant gaps between building maintenance research and the recent advances in the maintenance field typically applied in plant maintenance. We have identified 11 approaches/ areas of maintenance research and development that are either not fully utilised or else not explored in building maintenance. It is hoped that such list will help researchers in developing these areas and exploring its benefits in building maintenance. The potential benefits from the current development and implementation of BIM on building maintenance have been discussed. We believe that over the coming few years with the implementation of BIM significant amount of maintenance data will be accumulated. There is a need to develop methods and approaches that can help integrating BIM with the other computerised systems such as CAFM and CMMS to realise the benefits of BIM implementation in building maintenance. The development of integrated computerised intelligent systems is a potential approach to deal with this issue.

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