UNIVERSIDADE
BEIRA INTERIOR

Building Maintenance Management
Development of an integrated model of procedures

Jorge Gabriel Furtado Falorca

Tese para obtenção do Grau de Doutor em
Engenharia Civil
(3º ciclo de estudos)

janeiro de 2021

Date of Doctoral Proofs

11 December 2020

Jury Panel

President

Doctor *Vitor Manuel Pissara Cavaleiro*
Full Professor of the University of Beira Interior (UBI)

Members

Doctor *João Paulo de Castro Gomes*
Full Professor of the University of Beira Interior (UBI)

Doctor *José António Raimundo Mendes da Silva*
Associate Professor of the Faculty of Sciences and Technology of the University of Coimbra (FCTUC)

Doctor *José Manuel Sena Cruz*
Associate Professor of the University of Minho (UM)

Doctor *Inês dos Santos Flores Barbosa Colen*
Associate Professor of the Higher Technical Institute (IST) of the University of Lisbon

Doctor *Maria Fernanda da Silva Rodrigues*
Auxiliar Professor of the University of Aveiro (UA)

Dedication

For them,
By the strength they transmit,
To Anselmo and Margarida Falorca.

To know things well, we should know them in detail; and as that is in a manner infinite, our knowledge is always superficial and imperfect.

La Rochefoucauld, *Maxims*

Acknowledgments

I would like to acknowledge Prof. Dr. Raimundo Mendes da Silva and Prof. Dr. Rui Calejo Rodrigues for having agreed to be co-authors in some publications presented in this thesis.

I am still grateful to the anonymous reviewers who have read my work with professional care and attention and have offered very valuable comments and suggestions. Likewise, I have in great appreciation all exchange of views resulting from the several contacts with other colleagues, professionals and teachers, both national and international, which I have had the happiness of enjoying.

Finally, I would like to express my gratitude to my family for their unconditional support and encouragement. A special thanks to my wife, Prof. Dra. Isabel Gonçalves Falorca, for her patience and also for the very intelligent and knowledgeable observations with which she has provided me over the years.

Many thanks to all.

Preface

Over the last seventeen years, I have been increasingly studying and researching the Building Maintenance Management (BMM) subject, as many other connected aspects.

The first approach to this subject occurred in 2002, following a notable suggestion by Prof. Raimundo Mendes da Silva, when I expressed to him, my interest to develop a master's dissertation. At the time, I was very enthusiastic about the idea, since I would be able to investigate in more depth, an activity in which I had also been working for a number of years.

I was then able to verify that this was a matter which was not much discussed at a university level, since it seemed to be not yet consistently covered by undergraduate programs. In addition, there were still a small number of publications resulting from scientific research, despite at that time, some works of great quality had already started to appear.

After the defence of the master's dissertation, I have been conducting several publications, some in international journals and others in national and international congresses, events, etc. The perception of its good acceptance and in some cases the success achieved by the number of citations, was relevant in the sense of a greater stimulus to continue research in this area.

As a matter of fact, as my incursion into this domain was becoming more solid and comprehensive, I was aware that there were still other subjects to explore and develop, in addition to a preliminary approach, and further investigation could be useful.

Notice that it is still quite usual to see BMM to be performed in a poorly consolidated way, both technically and scientifically, being normally regarded as reactive or for problems resolution. So, to counteract this tendency, there is a need for greater vigour in order to evolve to more sustained ways of thinking and acting.

Therefore, as result of a thorough research and a careful study, I present this thesis with a set of scientific articles published in the last years in international journals and in congress proceedings. The research line followed, comprised a preliminary approach to a proposal for a model of building inspection and maintenance, evolving later to the conception of an algorithm of integrated procedures.

Through this study, it is basically intended to give a further contribution to knowledge advances in the BMM subject, by prescribing a set of actions thus enabling the management process to be more sustainable, both from an operational and integrative point of view, and fully in line with current technological and scientific challenges.

Resumo

Os edifícios estão entre os ativos mais valiosos de qualquer nação, no sentido em que proporcionam às pessoas um abrigo, espaços para trabalho e lazer, entre outras funções. Com os crescentes custos das novas construções, a necessidade de se fazer Manutenção de Edifícios (ME) torna-se ainda mais relevante, porque permite a qualificação do parque construído, ajuda a impulsionar a economia, melhora os padrões de bem-estar dos utilizadores, bem como a valorização dos espaços em geral. A ME, vista de uma forma estruturada, está atualmente a realizar progressos significativos, embora no âmbito das construções pareça existir ainda a necessidade de uma maior evolução. Contudo, a perceção generalizada é de que as ações de manutenção são ainda, na sua generalidade reativas, consistindo em atividades de correção, grandes reformas e intervenções não programadas, executadas principalmente em função dos orçamentos disponíveis e com o objetivo principal de restabelecer o estado operacional dos elementos e as condições normais de utilização. Enquanto no sector dos equipamentos, continuam a ser a experiência, as avaliações e as recomendações do fabricante, os aspetos mais determinantes do tipo e da frequência das operações de manutenção, ao nível dos elementos construtivos dos edifícios esta prática tem, apesar de tudo, vindo já a fazer um percurso positivo, embora ainda marcadamente distante daquilo que seria desejável. Há, portanto, no campo dos edifícios, condições para se evoluir para formas mais sustentadas de pensar e agir.

O objetivo principal desta tese é a apresentação das linhas gerais de um modelo amplo e integrado, desenvolvido para a Gestão da Manutenção de Edifícios (GME), ou seja, de um algoritmo base para um Sistema de Informação para Automatização de Procedimentos na GME, abreviadamente designado de SIAPME. Estabelecendo-se como um contributo adicional no sentido do avanço do conhecimento no tema da GME, este modelo propõe assim um conjunto de ações metodológicas que, caso utilizadas por uma organização deste setor de atividade (independentemente da sua dimensão), permitirão em teoria, que o processo de gestão se desenvolva de forma mais sustentável, tanto do ponto de vista operacional como da integração da informação, em linha com os atuais desafios tecnológicos e científicos.

Para o propósito referido, esta tese reúne uma seleção de artigos científicos, dispostos através de uma sequência que se julgou ser a mais coerente. Nesta perspetiva, a sua apresentação é estabelecida em linha com o desenvolvimento do trabalho de estudo e investigação realizado nos últimos anos. A metodologia seguida envolveu uma vasta revisão da literatura e a seleção e tratamento da informação considerada mais importante para os objetivos. A obtenção da literatura realizou-se essencialmente através do recurso a repositórios, sites institucionais, motores de busca na Internet, etc. Utilizaram-se também as

capacidades do MS Excel, tanto para o tratamento de dados numéricos quando necessário, como para a sistematização de conhecimentos e ideias, em particular para a projeção do algoritmo do SIAPME, que se baseou na elaboração e apresentação de um vasto conjunto de organogramas e fluxogramas inseridos em diversas folhas, com hiperligações entre si. Para o ensaio da adaptação experimental da função de Gestão de Recursos prevista no modelo SIAPME, utilizou-se o Visual Basic.

Os resultados gerais obtidos parecem ser bastante positivos, sobretudo quando se comparam com casos semelhantes. Com o desenvolvimento do SIAPME, conseguiu-se ter disponível, de forma organizada, um estado da arte conciso e aprofundado, tendo-se obtido um algoritmo de conceção inovadora para GME, que se perspetiva muito abrangente e com maior capacidade de integração da informação do que muitos dos modelos atualmente existentes. Julga-se que após um eventual processo de evolução do SIAPME para uma ferramenta informática, este poderá apresentar características transversais às consideradas nas classificações dos sistemas Computer-Aided Facility Management (CAFM) e Computer Maintenance Management System (CMMS), cobrindo praticamente todos os aspetos de categorias de aplicação que normalmente abrangem, como sejam a gestão de edifícios, a gestão de espaços, etc.

No geral, julga-se que os resultados do presente estudo poderão dar um importante contributo no sentido de uma alteração de paradigma relativamente à forma como a GME é ainda atualmente vista e praticada.

Palavras-chave

Edifícios, manutenção de edifícios, gestão de edifícios, algoritmo de procedimentos, modelos e sistemas, sistemas de informação, aplicações computadorizadas.

Abstract

Buildings are some of the most valuable assets of any nation, in the sense that they provide people shelter, places to work and leisure, and so many others functions. With the rising costs of new buildings, the need for Building Maintenance (BM), has become even more relevant, since it allows the qualification of the built portfolio, helps boosting the economy, upgrades life well-being of users, as well as the appreciation of spaces in generally. BM, when seen in a structured way, is currently making significant progresses; although, regarding buildings, there seems to be a need for further development. However, the widespread perception is that Maintenance Actions (MA) are still, in their generality, reactive, consisting of corrective actions, major reforms and unscheduled interventions, carried out mainly on the basis of the available budgets, with the main objective of restoring the operational status of elements and the normal utilisation conditions. While in the equipment sector, still are the experience, the evaluations and the recommendations of the manufacturers the most decisive aspects for the type and frequency of maintenance operations, at the level of constructive elements of buildings, this practice is, nevertheless, already making positive developments, although it is still bluntly far from what would be desirable. Therefore, regarding the buildings' subject, there are aspects needing improvements towards more sustainable ways of acting and thinking.

The main objective of this thesis is the presentation of the general lines of a broad and integrated model, developed for BMM, that is, a base algorithm for an Information System for Automatisation of Procedures in the BMM, referred to in an abbreviated form as SIAPME (initials in Portuguese). By establishing himself as an additional contribution to deepen knowledge on the subject of BMM, this model thus proposes a set of methodological actions - which, when used by an organisation of this sector of activity (regardless of its size), will, in theory, allow the management process to develop in a more sustainable manner. This, both from an operational and the information integration point of view and in line with the current technological and scientific challenges.

For the above purpose, this thesis gathers a selection of scientific articles, arranged through a sequence that was deemed to be the most coherent. In this perspective, its presentation is established in line with the development of study and research work carried out in recent years. The methodology followed involved a broad literature review as well as the selection and treatment of information considered most important for the purposes. Literature was gathered relying mostly on repositories, institutional sites, Internet search engines, etc. MS Excel capabilities were also used, both for treatment of numerical data (when necessary) as for systematising knowledge and ideas, particularly in order to design the SIAPME algorithm - which was based on the elaboration and presentation of a vast set of organisation charts and

flow charts, inserted in several sheets, with hyperlinks to each other. Visual Basic was also used to develop the experimental adaptation of the Resources Management function foreseen in SIAPME model.

The overall results achieved from this model seem to be quite positive, especially when compared to similar cases. For development of SIAPME, a concise and in-depth state of the art has been carried out, available in an organised manner; also, an innovative design algorithm for GME has been succeeded, planned to be quite broad and with a larger capacity of information storage that many of current models seem to lack. It is believed that after an eventual SIAPME evolving process to an informatics tool, it may present transversal characteristics to the previously considered ratings of CAFM and CMMS systems, basically covering every single aspects of its application categories, those being building management, space management, etc.

Overall, it is believed that the results of this study could make significant contribution towards a paradigm shift regarding the way BMM is still seen and practised.

Keywords

Buildings, building maintenance, building management, algorithm of procedures, models and systems, information systems, computer applications.

Contents

List of Figures

Chapter 2

2.1. ***Building maintenance and management – theoretical aspects and correlations***

2.2. ***A model plan for buildings maintenance with application in the performance analysis of a composite façade***

Chapter 3

3.1. ***Research measurement of knowledge advances in building maintenance issues***

List of Tables

Chapter 2

Chapter 3

List of Acronyms

AB'sC	Assessment of Buildings 'Condition
AFNOR	Association Française de Normalisation
AIJ	Architectural Institute of Japan
AM	Ações de Manutenção; Asset Management
AR	Augmented Reality
AVAC	Aquecimento, Ventilação e Ar Condicionado
BE	Building Element(s)
BIM	Building Information Model(l)ing
BM	Building Maintenance
BMM	Building Maintenance Management
BMMP	Building Maintenance Management Process
BMMS	Building Maintenance Management System
BMS	Building Management Systems
BS	British Standard
BSI	British Standard Institution
CAD	Computer Aided Design
CAFM	Computer-Aided Facility Management
CBM	Condition-Based Maintenance
CEN	Comité Européen de Normalisation / European Committee for Standardization
CER	Caracterização do Estado de Referência
CI	Continuous Improvement
CIB	International Council for Research and Innovation in Building and Construction
CLT	Comunidade Lean Thinking
CMMS	Computer Maintenance Management System
CP	Company
CP's	Conjuntos Patrimoniais
CSTB	Centre Scientifique et Technique du Bâtiment
CT	Costumers
DBMC	Durability of Building Materials and Components
DCLG	Department for Communities and Local Government
DfEE	Department for Education and Employment
DHPW	Department of Housing and Public Works
DHS	Decent Home Standard
EAMC	The European Asset Management Committee
EE	Elemento do Edifício
EFNMS	European Federation of National Maintenance Societies
EPIQR	Energy Performance Indoor Environment Quality Retrofit
ET	External Partners
ETICS	External Thermal Insulation Composite System
EU	European Union

EUA	Estados Unidos da América
FEUP	Faculdade de Engenharia da Universidade do Porto
FM	Facilities Management
FMA	Facility Management Association of Australia
FMECA	Failure Mode, Effects and Criticality Analysis
FMEA	Failure Modes and Effects Analysis
FMIS	Facility Management Information System
GAMF	General Asset Management Functions
GE	Gestão de Edifícios
GG	Gestor Geral
GIS	Geographic Information System
GM	Gestão da Manutenção
GME	Gestão da Manutenção de Edifícios
GSA	General Services Administration
GTIC	Gestão Técnica, Inteligente e Centralizada
HHSRS	Housing Health and Safety Rating System
HMSO	Her Majesty's Stationery Office
IAM	The Institute of Asset Management
ICT	Information and Communication Technology
ISI	International Scientific Information
ISO	International Organization for Standardization
IST	Instituto Superior Técnico
IWMS	Integrated Workplace Management System
JIT	Just-in-Time
KPI	Key Performance Indicators
LBM	Lean Building Maintenance
LC	Lean Construction
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LERC	Lean Enterprise Research Center
LNEC	Laboratório Nacional de Engenharia Civil
LPS	Last Planner System
MA	Maintenance Actions
MAEC	Método de Avaliação do Estado de Conservação de Imóveis
ME	Manutenção de Edifícios
MIS	Management Information System
MM	Maintenance Management
MMS	Maintenance Management System
MS Excel	Microsoft Office Excel
NBR	Norma Brasileira
NDT	Non-Destructive Testing
NIBS	National Institute of Building Sciences
NP	Norma Portuguesa
O&M	Operação e Manutenção

OT	Ordem de Trabalho
PAM	Physical Asset Management
PAS	Public Available Specification
PDCA	Plan, Do, Check, Act
PE	Parque Escolar
PEM	Plano Estratégico de Manutenção
PGME	Processo de Gestão da Manutenção de Edifícios
PIMEC	Plano de Inspeção e Manutenção em Edifícios Correntes
PM	Preventive Maintenance
PMS	Property Management System
PFM	Potential Failure Mode
QDHPW	Queensland Department of Housing and Public Works
RCM	Reliability Centred Maintenance
REH	Regulamento de Desempenho Energético dos Edifícios de Habitação
RFID	Radio Frequency Identification
RICS	Royal Institution of Chartered Surveyors
SCGM	Sistema Computadorizado de Gestão da Manutenção
SGME	Sistema de Gestão da Manutenção de Edifícios
SGM	Sistema de Gestão da Manutenção
SI	International System of Units
SIAPME	Sistema de Informação para Automatização de Procedimentos na Gestão da Manutenção de Edifícios
SIG	Sistema de Informação Geográfica
SIGMO	Sistema Informático de Gestão de Manutenção e Operação
SMP	Strategic Maintenance Planning
SP	Suppliers
ST	Storeroom
TIC	Tecnologias de Informação e Comunicação
TOBUS	Tool for Selecting Office Building Upgrading Solutions
TPM	Total Productive Maintenance
TPS	Toyota Production System
UK	United Kingdom
USA	United States of America
VR	Virtual Reality
WCM	World Class Maintenance
WEB	World Wide Web
WO	Work Order

Units

The following SI units were used:

Length	m
Area	m^2

Resumo alargado

Nesta secção resume-se, de forma alargada e em Língua Portuguesa, o trabalho de investigação descrito na tese de doutoramento intitulada "Building Maintenance Management: development of an integrated model of procedures".

Numa primeira fase faz-se uma introdução com o enquadramento do assunto, os objetivos e a metodologia seguida e uma breve descrição das principais contribuições.

Posteriormente, apresenta-se a organização da tese, com uma breve descrição da linha de abordagem entendida como sendo a mais adequada para a apresentação e enquadramento das diferentes contribuições selecionadas.

O corpo central deste resumo alargado apresenta uma visão genérica dos assuntos abordados, fazendo um resumo parcial, transversal e relativo a cada contribuição, devidamente enquadrado nos tópicos dos diferentes pontos dos dois principais capítulos.

Por último, apresentam-se as conclusões, bem como breves notas sobre determinados aspetos que poderão eventualmente merecer mais desenvolvimentos e investigação futura.

Introdução

Enquadramento do assunto

O presente estudo aborda genericamente o tema da GME. Trata-se de um assunto que nas últimas décadas não tem sido suficientemente explorado em Portugal, tanto ao nível do sector da construção, onde foi algo negligenciado por ausência de políticas de promoção do mesmo, como em certa medida no meio científico em geral, eventualmente por ser um tema que não despertasse maior atenção devido ao modelo de desenvolvimento que vinha a ser seguido. A juntar a tudo isto, o Estado e o poder político parecem ter adotado um papel alheio, caracterizado por uma quase ausência de medidas legislativas adequadas.

Porém, mais recentemente, fruto da crise económica com que se debateu o país e da consequente diminuição drástica dos índices de construção nova, a situação parece estar a inverter-se, com o despontar de um maior interesse nesta área, talvez por força de uma reorientação do sector da construção para a reabilitação urbana e por se ter tomado maior consciência do nível de degradação do parque de edifícios existente. Também a nível académico, e particularmente desde meados da década de 2000, parece ter-se iniciado uma fase de avivamento do assunto, visível sobretudo pelo súbito crescimento ocorrido no número

de teses e de dissertações. Também foram realizados mais eventos públicos relacionados e é percetível o aumento da atividade económica neste nicho de interesse, com um contínuo surgimento e fortalecimento de empresas do sector.

Por isso, particularmente ao nível dos edifícios, é importante diferenciar a utilização combinada de técnicas de gestão da informação e de engenharia, tendo por objetivo acompanhar o seu ciclo de vida e incluir especificações relativas à gestão e ao controlo da sua manutenção, a eventuais modificações, substituições e ao acompanhamento dos seus tipos e níveis de utilização. A ME, vista de uma forma estruturada, parece estar assim a realizar progressos significativos, embora no âmbito das construções exista ainda muito trabalho a realizar. Portanto, apesar de o clima económico e a conjuntura atual da construção permitir reforçar a ideia de que a atividade de inspeção e manutenção terá a curto/médio prazo um significativo reforço da sua escala de implementação e que ainda recorre a métodos próprios, ela vê-se já hoje, dadas as circunstâncias, perante clientes e situações de exigência crescentes, que procuram serviços eficazes, de maior qualidade e rapidez, sem que isto envolva acréscimos de custos significativos.

Veja-se por exemplo, a crescente premência de muitas entidades púbicas, público-privadas e privadas em optarem por recorrer a serviços externos contratualizados que garantam o eficaz funcionamento do seu património, eliminado assim departamentos internos que muitas vezes são inaptos, ao mesmo tempo que seguem a via da desconcentração das suas funções e a modernização administrativa. E ao invés, entidades que tem ótimas estruturas de recursos humanos e tentam otimizar o seu funcionamento, optando elas próprias por investir no desenvolvimento de ferramentas e métodos mais adaptados à sua realidade interna.

Mas esta opção exige assim, tanto das empresas e de outras entidades ligadas ao sector, bem como dos diversos intervenientes envolvidos, uma grande capacidade de adaptação, diligência e inovação. Por isso, é já muito comum o recurso a meios que possam facilitar essas funções, como por exemplo, à vasta gama de opções em Tecnologias de Informação e Comunicação (TIC), especificamente daquelas mais direcionadas para o apoio à Gestão da Manutenção (GM) e em particular de software ou de aplicações informáticas relacionadas. Neste caso, existem atualmente disponíveis no mercado um grande número de opções com diferentes abordagens em termos de integração, funções e graus de êxito. Porém, quanto à abrangência em concreto aos elementos construtivos e as muitas outras particularidades ligadas ao próprio ato de gestão, às questões do ambiente e da sustentabilidade, à energia, conforto, à adaptação a uma legislação cada mais extensa, entre muitos outros aspetos, verifica-se uma escassez ou ausência de aplicações que permitam uma utilização de larga amplitude, sejam flexíveis e mais fundamentadas em modelos ou suportes cientificamente estudados e testados.

Neste sentido, e porque no essencial a atividade de GM não deve ser realizada de modo improvisado e casual, parece imprescindível o surgimento e desenvolvimento de contributos

que visem o aperfeiçoamento dos modos de gestão dos ativos imóveis através de um bom planeamento dos processos e das atividades, da sua execução conforme planeado, da avaliação de resultados, do desencadear de ações de operacionalização e de melhoria em função das necessidades, da integração da informação e do conhecimento, entre outros aspetos. Saliente-se que hoje em dia, a utilização eficiente da informação é uma condição crítica de sucesso para qualquer organização.

Face ao exposto, acredita-se que um dos caminhos a seguir passa então por um maior estudo e desenvolvimento de linhas de orientação para a automatização de procedimentos, que sejam cientificamente baseadas e que possibilitem abrir caminho ou servir de base a aperfeiçoamentos ou a novas formas ou ferramentas para a realização de uma ME de nível superior. Esta é seguramente uma das vias que proporcionará a esta atividade ter um desenvolvimento estratégico mais sustentável.

Objetivos e metodologia seguida

O objetivo principal deste estudo foi traçar as linhas gerais de um sistema de informação que se pretende venha a ser real em termos de suporte informático e que seja facilitador do desempenho funcional de qualquer organização, independentemente da sua dimensão e do património em causa. Portanto, com base numa organização coerente, a intenção foi estabelecer um conjunto de princípios orientadores ou de estratégias sustentáveis que possibilitem no futuro, vir a usufruir-se de uma plataforma completamente automatizada e simplificadora de procedimentos, através de um modelo base de conceção inovador, mais abrangente e integrativo de toda a informação do que muitos dos sistemas ou programas atualmente existentes. Ao algoritmo de procedimentos projetado visando um sistema de informação, atribui-se-lhe a designação genérica de SIAPME.

Em termos genéricos, a metodologia seguida consistiu das seguintes etapas principais:

- Estudar a diversidade de elementos bibliográficos existentes relacionados com as diferentes temáticas, de forma a reunir, assimilar e/ou a percecionar o conhecimento intrínseco;
- Reunir e estruturar a informação resultante mais importante para a concretização dos principais objetivos propostos;
- Analisar e reunir, num catálogo bibliográfico, os títulos da bibliografia relacionados com a manutenção e que se considerassem de interesse geral para a atividade de um gestor de edifícios, fazendo depois o seu tratamento estatístico e o respetivo tratamento de resultados (estudo bibliométrico);
- Na sequência da etapa anterior, extrair uma perspetiva geral (e as parciais que fossem possíveis) acerca da evolução do conhecimento;

- Investigar e entender o conhecimento acerca de alguns aspetos base de gestão utilizados no campo da manutenção industrial uma vez que se considerou importante reter algum domínio de conhecimento nesse campo para também ser possível aplicá-lo em concreto. Neste particular, saliente-se que grande parte da teoria e da operacionalidade no campo da ME é intrinsecamente proveniente daquele importante e avançado sector de atividade, pelo que se considerou que o seu conhecimento não se deveria desprezar;
- Investigar e entender o conjunto de modelos, procedimentos ou métodos desenvolvidos, utilizados ou com interesse para a GME;
- Investigar e aprofundar o conhecimento acerca do Pensamento Lean – uma vez que se trata de um assunto também amplamente estudado e com aplicação recente ao sector da construção. Além disso, pretendeu-se verificar de que forma se poderia utilizar na ME e nesse sentido sugerir em concreto uma eventual proposta teórica de aplicação.

Em geral, a literatura relevante foi obtida por consulta de repositórios em bibliotecas e maioritariamente por meio do Google, Google Acadêmico, ResearchGate, ScienceDirect, B-On, Emerald Insight, ligações a sites institucionais, periódicos, etc., abrangendo uma ampla variedade de tipos de publicações, páginas da Web e outros. O processamento da informação foi realizado com base na separação de cada publicação de acordo com os temas e subtemas que interessavam a este trabalho.

Para o ensaio de adaptação experimental da função de gestão relativa à Gestão de Recursos prevista no modelo SIAPME, utilizou-se uma linguagem de programação Visual Basic, envolvendo uma pré-aprendizagem feita de forma autónoma.

Principais contribuições

Esta secção descreve brevemente as sete principais contribuições científicas resultantes do trabalho de investigação apresentado nesta tese.

A primeira contribuição apresenta brevemente o conceito de ME, alguns aspetos sobre as fases que compõem o ciclo de vida dos edifícios e os tipos de gestão mais viáveis na fase de utilização. A comunicação também procura chamar a atenção para a importância de aprofundar e discutir esses tópicos e suas interdependências. É basicamente uma revisão de literatura introdutória.

A segunda contribuição desta tese refere-se a uma abordagem a um modelo para um Plano de Inspeção e Manutenção para Edifícios Correntes (abreviadamente PIMEC). Esse plano foi concebido para utilização genérica e pode ser personalizado para cada tipo de solução de construção, para cada elemento da construção e/ou eventualmente para cada material de

construção. O teste e validação do modelo baseou-se na inspeção de uma vasta área de fachadas de vários edifícios revestidas com ETICS. O objetivo daquele estudo foi ampliar o conhecimento sobre os métodos organizados de implementação de manutenção em elementos de construção que requerem atenção especial ao longo de sua vida útil, a fim de aumentar a durabilidade geral e evitar a incidência de custos supérfluos durante a fase de utilização. Com um ensaio prático, foi ainda possível detalhar o modelo de manutenção aplicado ao ETICS e proporcionar um conhecimento aproximado de seu comportamento em serviço e da eventual durabilidade, contribuindo também assim para a sua divulgação e para que este tipo de acabamento de fachada seja um material mais utilizado, principalmente devido ao seu excelente desempenho em termos de redução das perdas de energia através da envolvente. Portanto, a partir deste trabalho precursor, foram disponibilizadas um conjunto de ideias base no sentido de se conseguir ter uma organização mais adequada de certos aspetos, relacionados em particular, com a inspeção e manutenção de um edifício corrente.

A terceira contribuição consiste essencialmente num estudo bibliométrico para avaliação do progresso geral do conhecimento em ME, que possibilitou analisar, de forma aproximada, o crescimento de todo o corpo da produção literária com este campo relacionada e determinar quais as linhas de pesquisa que podem requerer mais estudo e desenvolvimento. Este trabalho envolveu um vasto estudo de pesquisa e uma sistematização bibliográfica de diferentes aspetos. Utilizando vários meios de apoio, foi feita uma pesquisa detalhada de mais de 2.000 títulos de publicações. Os dados da pesquisa foram agrupados em seis indicadores bibliográficos pré-definidos: Livros, Artigos em Revistas, Artigos em Eventos (ambos do tipo académico, técnico ou profissional), Teses & Dissertações, Normas e Outros Documentos. Os resultados foram gradualmente organizados num catálogo de recursos bibliográficos, para o qual se utilizaram os recursos do MS Excel, que também auxiliou no processo subsequente de contagem e análise estatística.

A quarta contribuição é um estudo resumido de revisão bibliográfica sobre diversos modelos, sistemas e métodos para GM, referindo alguns daqueles com origem e aplicação na indústria em geral, bem como outros mais importantes já desenvolvidos e aplicados em edifícios e parques de edifícios. Este foi um tipo de estudo que contribuiu com importância para o desenvolvimento do SIAPME. Esta contribuição contém também, de forma antecipada, uma breve análise crítica comparativa, na qual se apresentam alguns dos aspetos de convergência do sistema relativamente aos diferentes tópicos analisados, bem como a importância da sua consideração para a eficácia e inovação de valor acrescentado daquela proposta de algoritmo de procedimentos.

Na quinta contribuição apresenta-se uma proposta para uma abordagem conceitual à aplicação do conceito Lean na GME. Como resultado de uma revisão da literatura no campo da filosofia Lean, este trabalho identifica vários aspetos que podem contribuir para uma maior eficácia de procedimentos na GME. Sugere-se assim a introdução de algumas práticas

Lean nos fluxos de um processo genérico de GME, cuja prática é sugerida para ser conhecida como Manutenção de Edifícios Lean (Lean Building Maintenance ou LBM). Os resultados deste ensaio idealizam uma melhoria do desempenho de atuação através de uma maior agilidade nos procedimentos, de forma a reduzir ou eliminar os desperdícios mais frequentes. Pretende-se também que este conhecimento esteja na base conceptual do desenvolvimento de novas ferramentas mais eficientes e relacionadas como é o caso daquela que pode resultar do SIAPME.

A sexta contribuição apresenta então as linhas gerais de um algoritmo de procedimentos para utilização na GME, genericamente designado de SIAPME. Com base numa ampla revisão da literatura (aqui novamente atualizada), este trabalho consiste num exercício prático exploratório, que envolve vários organogramas com diversas interconexões, oferecendo uma visão geral de um conjunto de estratégias alternativas, bem fundamentadas e integradas para a gestão de património, independentemente de se tratar de um edifício ou um conjunto de edifícios. Através dos procedimentos do SIAPME, o Gestor Geral poderá ter uma perspetiva sobre a ampla gama das suas funções, cobrindo quase todos os aspetos fundamentais para uma manutenção eficiente e integrada, com controlo ideal de todos os participantes no processo. Trata-se de uma ideia conceitual que ao introduzir questões tecnológicas e emergentes, parece ser vantajosa para a GME.

Decorrente do desenvolvimento do SIAPME, conforme descrito nos últimos parágrafos, a sétima contribuição refere-se essencialmente à apresentação das linhas gerais de uma adaptação computadorizada testada para uma das seis Funções Gerais de Gestão do Património previstas pelo SIAPME. Com efeito, a importância que assumem os Recursos de Suporte (gestão de Meios, das funções da Organização e das TICs), é fundamental para o completo sucesso da abordagem proposta pelo SIAPME. Assim, foi utilizada, apenas para efeitos de estudo, a linguagem de programação Visual Basic e elaborada uma versão básica em computador. Os resultados alcançados evidenciam as suas potencialidades, particularmente no que se refere à identidade e à eficácia dos procedimentos previstos, bem como à integração sustentável de todas as informações necessárias para uma gestão eficiente.

Organização da tese

Esta tese está organizada em quatro capítulos.

O capítulo 1 faz o enquadramento do assunto aqui tratado, apresenta os objetivos e a metodologia seguida, uma breve descrição das principais contribuições e como está organizada a tese.

No capítulo 2 faz-se uma abordagem preliminar que inclui a primeira e segunda contribuição. Ou seja, no ponto 2.1. apresenta-se uma revisão da literatura introdutória, relativa a diversos

aspetos teóricos e de correlações no âmbito da ME e respetiva gestão. Posteriormente, no ponto 2.2., aborda-se um modelo para PIMEC e o respetivo teste e validação baseado na inspeção de uma vasta área de fachadas de vários edifícios revestidas com ETICS.

O capítulo 3 compreende algumas das etapas do desenvolvimento de uma aplicação abrangente para a gestão integrada da ME, que culminaram com a apresentação das linhas gerais do SIAPME e de uma pequena adaptação computadorizada para uma das suas funções. Genericamente, este capítulo abrange da terceira até à sétima contribuição, sendo que destas, as três primeiras são fundamentalmente de revisão bibliográfica. Ou seja, no ponto 3.1. inclui-se um estudo bibliométrico para avaliação dos progressos gerais no conhecimento em ME; o ponto 3.2. compreende genericamente uma breve revisão bibliográfica sobre diversos modelos, sistemas e métodos para GM; e no ponto 3.3 apresenta-se uma proposta para uma abordagem conceitual à aplicação do conceito Lean na GME.

Os preceitos base e as linhas gerais do SIAPME são então expostos no ponto 3.4. e seguidamente no ponto 3.5., é apresentada, em termos gerais, a adaptação computadorizada testada para uma das seis Funções Gerais de Gestão do Património previstas pelo modelo referido.

No capítulo 4 apresentam-se as conclusões. Faz-se um enquadramento, a análise aos principais resultados obtidos, uma avaliação dos objetivos, as dificuldades e incluem-se ainda breves notas sobre eventuais desenvolvimentos futuros.

Modelo para plano de inspeção e manutenção em edifícios correntes – uma abordagem preliminar

No capítulo 2 faz-se uma abordagem preliminar que inclui a primeira e segunda contribuição, ou seja, apresenta-se inicialmente uma revisão da literatura introdutória, relativa a diversos aspetos teóricos e de correlações no âmbito da ME e da respetiva gestão. Posteriormente analisa-se um modelo para PIMEC e diversos aspetos do seu ensaio e validação com base na inspeção de uma vasta área de fachadas de vários edifícios, revestidas com ETICS.

Manutenção e gestão de edifícios - aspetos teóricos e correlações

Aspetos preliminares

As funções de gestão e manutenção tem tido um papel fundamental, uma vez que são consideradas como uma responsabilidade essencial no sentido de preservar e maximizar a utilidade e o valor dos edifícios. Por isso, o ramo da ME passa a ter cada vez mais uma

importância decisiva na sua gestão global, contribuindo no geral para o aumento da vida útil dos edifícios, retardando o seu envelhecimento bem como o controlo dos custos.

Neste trabalho expõem-se alguns dos mais importantes aspetos teóricos abordados num estudo académico (Falorca, 2004) e que ainda se consideram muito atuais, relacionados com a necessária interdependência entre os princípios básicos de manutenção, as diferentes etapas do ciclo de vida dos edifícios e a Gestão Técnica durante a fase de utilização. É desejável que a ME surja numa lógica de planeamento racional de estratégias de intervenção periódica (isoladas ou combinadas) e de ações administrativas aplicadas durante a vida dos elementos construtivos, por forma a produzirem-se constantemente informações úteis, para se aprimorar as técnicas e se aprofundar o conhecimento científico.

Aspetos teóricos sobre manutenção de edifícios

A palavra "manutenção" pode ser genericamente definida como: "1. o ato de manter…; 2. o estado de ser mantido …; 3. cuidado ou manutenção, de maquinaria ou propriedade …" (Dictionary.com, s.d.); ou como: "O ato de manter algo em bom estado, verificando-o ou reparando-o regularmente…" (Hornby, 2002). O conceito pode ainda ser proveniente do processo industrial com igual aplicação aos edifícios, pelo que "a manutenção é a combinação das ações de gestão, técnicas e económicas, aplicadas aos bens para otimização dos seus ciclos de vida" (Cabral, 1998; Flores, 2002). Quando se aplica aos edifícios, a manutenção pode fazer parte dos procedimentos gerais da sua Gestão Técnica, cuja atividade se adequa melhor ao campo da Engenharia Civil, abrangendo todos os tipos de ações para garantir o desempenho das soluções construtivas, seja corrigindo desvios ou pela avaliação das condições de operação.

Deve-se salientar que, ocasionalmente, essa palavra pode surgir para muitos interessados no setor da construção com um sentido generalista e muitas vezes pode ser confundida com a Reabilitação de Edifícios ou até mesmo ser usada frequentemente com uma dupla conotação: conservação e renovação. Em qualquer caso, mais importante do que a definição de manutenção, é que o trabalho certo seja realizado. Segundo alguns autores (Wood, 2009), a ME "certa" (ou "RIGHT" Building Maintenance) pode ter determinadas componentes (Tabela 1 – pág. 15, pt. 2.1.).

Estratégias de manutenção

Com a previsão e realização de estratégias de manutenção adequadas, é possível determinar os instantes, durante a vida útil dos elementos, em que se deve proceder a intervenções de reparação ou de substituição. Desta forma, otimizam-se custos e recursos que minimizarão gastos desnecessários para tais intervenções. Na ME, as estratégias de manutenção reativa e proativa são geralmente as mais consideradas (Figura 1 – pág. 15, pt. 2.1.).

O processo do ciclo de vida dos edifícios

O ciclo de vida de um edifício inclui várias etapas: (i) promoção e planeamento, (ii) conceção e projeto; (iii) fabrico dos materiais e componentes; (iv) construção; (v) utilização e manutenção; vi) demolição (Flores, 2002; Branco, 2003). Um edifício em fase de utilização é um sistema de características próprias e difícil de compreender. Essas características interligam-se para garantir o desempenho do todo, que é o edifício. O desempenho só é alcançado através de mecanismos cuja complexidade são, na sua grande maioria, impeditivos de serem analisados e interpretados. Tais dificuldades surgem principalmente dos seguintes aspetos (Abrantes e Calejo, 1994): i) grande diversidade de atuação dos utilizadores; ii) formas corretas e incorretas de utilização; iii) grande número de respostas funcionais que o edifício desempenha; iv) grande variedade de elementos, componentes e materiais que o constituem; v) é resultado de um faseamento e não de uma ação única. A Figura 2 (pág. 20, pt. 2.1.) procura caracterizar a fase de serviço/utilização e manutenção, o comportamento e os fatores de degradação de um edifício.

A gestão de edifícios

Um edifício pode considerar-se como um recurso e um bem material. Assim, um dos objetivos fundamentais da sua utilização passa pela otimização destes aspetos. O recurso edifício é constituído pelo imóvel ou edifício físico com todas as suas características técnicas. A obtenção de uma resposta funcional, dentro dos parâmetros estabelecidos aquando da sua conceção, durante o maior período de tempo possível e com o menor custo, implica a maximização do seu desempenho durante a fase de utilização. Esta situação só é possível se existir uma postura do utilizador ou do gestor que é típica da gestão e que se pode caracterizar por (Rodrigues, 2003): i) otimizar a utilização; ii) promover ações de manutenção; iii) analisar comportamentos e proceder adequadamente; iv) proteger. Um edifício é um bem, porque apresenta características muito particulares e bem definidas, entre as quais se destacam a longevidade e o valor patrimonial enquanto ativo real (Natividade, 2002). No que diz respeito à longevidade, estão associadas questões de durabilidade que resultam da garantia de desempenho e da importância económica que assume a idade útil do edifício. O gestor de edifícios tem vários deveres e responsabilidade e a si cabe a Gestão Técnica, Económica e Funcional ou Social (Figura 3 - pág. 22, pt. 2.1.).

Observações Finais

No contexto decorrente da Gestão de Edifícios (GE), a implementação de metodologias de manutenção, constitui parte integrante de todas as fases de um processo de empreendimento da construção. É premente identificar a importância dos diferentes patamares desse processo, para um adequado sistema de gestão dos edifícios, nos quais haja a intervenção constante dos projetistas e se proceda a uma sólida recolha de informação, a ser utilizada como conhecimento base na realização de empreendimentos futuros.

Ressalta-se também a importância dos atos de gestão em torno da temática da manutenção e da durabilidade dos edifícios. Assim, no caso particular da GE, há que proceder segundo três perspetivas.

A primeira diz respeito à implementação da Gestão Técnica, a qual abrange todo o tipo de ações com o objetivo de garantir o desempenho das soluções construtivas, corrigir os desvios funcionais e avaliar as condições de funcionamento (no fundo, representa a maioria dos procedimentos da manutenção).

Numa segunda perspetiva, há que fazer a Gestão Económica, para se controlar ao longo da vida do edifício, a influência dos custos diferidos no balanço económico do investimento feito com o mesmo.

Por último, há que garantir a Gestão Funcional ou Social das construções, ou seja, fomentar a adequada utilização dos edifícios, sobretudo definindo regras e enquadrando comportamentos que satisfaçam as necessidades vulgares dos seus utilizadores.

Em toda esta perspetiva, é necessário conhecer a teoria das estratégias da ME, que se apresentaram sucintamente. A Figura 4 (pág. 23, pt. 2.1.) procura sistematizar algumas das correlações entre as questões abordadas.

Modelo para plano de manutenção de edifícios com aplicação na análise de desempenho de um revestimento compósito de fachada

Introdução

Com os custos crescentes das novas construções, a necessidade de se fazer ME torna-se mais relevante, porque permite a qualificação do parque construído, ajuda a impulsionar a economia, melhora os padrões de bem-estar dos utilizadores, bem como a valorização dos espaços em geral. Além disso, os desafios de qualidade dos edifícios passam pelo respeito por regras relativas ao meio ambiente. A necessidade de economizar energia e recursos naturais tornou-se obrigatória e essencial. Novos regulamentos têm imposto um padrão mínimo de conservação de energia em novos edifícios, impulsionando a melhoria energética e, consequentemente, os custos de aquecimento estão diminuindo, dando assim uma contribuição importante para a proteção ambiental. Desta forma, os requisitos para o isolamento térmico da envolvente dos edifícios aumentaram significativamente nos últimos anos. Os sistemas de isolamento de paredes exteriores aparentemente têm uma expectativa de vida que pode corresponder, se os edifícios nos quais eles são aplicados forem mantidos corretamente. Como resultado, têm sido colocadas grandes exigências aos ETICS, de maneira que a vida útil funcional deste material deve continuar a ser estudada. Este estudo refere-se a um modelo para PIMEC, que foi concebido para utilização genérica e que pode ser

personalizado para cada tipo de solução de construção, para cada elemento da construção e/ou eventualmente para cada material de construção. Para testar e validar o modelo, decidiu-se analisar fachadas de edifícios cobertas com ETICS (sistema de revestimento delgado armado sobre isolante). A Universidade de Coimbra, adotou esta técnica de isolamento para um grande número de edifícios erguidos em alguns dos seus campus, resultando assim numa amostra experimental impressionante para este trabalho de pesquisa. O objetivo é ampliar o conhecimento sobre métodos organizados de implementação de manutenção em elementos de construção que requerem atenção especial ao longo de sua vida útil, a fim de aumentar a durabilidade geral e evitar a incidência de custos supérfluos durante a fase de utilização. Por intermédio de testes práticos, foi possível detalhar o modelo de manutenção aplicado ao ETICS, fornecendo um conhecimento aproximado acerca do seu comportamento em serviço real e a durabilidade provável. Os resultados têm implicações importantes para gestores e investigadores, pois fornecem algumas noções sobre o mecanismo de como um método de manutenção de um edifício permite obter importantes resultados teóricos sobre a durabilidade dos seus elementos.

Abordagem ao modelo PIMEC

Um plano de manutenção é um conjunto de especificações realizadas no contexto do processo de manutenção, sendo projetado para programar ações de preservação. O desenvolvimento dessas metodologias deve começar ainda na fase de projeto e ser objeto de uma atualização dinâmica durante a fase de utilização. Estes planos constituem-se como ferramentas preciosas de apoio às entidades com responsabilidade na gestão dos edifícios, cujo objetivo principal é monitorar o desempenho das soluções construtivas, elementos ou componentes, com uma correção constante das condições de operação e, em seguida, emitir advertências conforme necessário.

O estabelecimento de um plano de inspeção e manutenção em edifícios correntes, sendo encaminhado para o PIMEC, compreendeu diversas fases fundamentais e cada uma dessas fases apresenta uma subestrutura de procedimentos devidamente referenciada (utilizando, por exemplo, letras e algarismos) e com hierarquia. Desta estrutura resultou um conjunto de linhas de orientação para a formação de um dossier técnico organizado e permanentemente atualizado, produzido por uma estrutura de pessoal pertencente ao sector da Gestão Técnica do dono de obra.

Estrutura principal

Neste ponto é apresentada a estrutura base do PIMEC, a partir da qual se decompõem várias outras subestruturas de procedimentos. Assim, há que ter em conta duas fases iniciais: a identificação dos principais elementos constituintes do edifício em causa e a aplicação do plano aos mesmos (Figura 1 - pág. 32, pt. 2.2.). As designações e referências atribuídas são meramente exemplificativas. Pretende-se que o dossier do plano seja assim organizado e

constantemente atualizado de acordo com aquela estrutura, incluindo toda a informação existente em projeto e recolhida posteriormente na fase de utilização.

Identificação dos elementos principais do edifício

Para a modelação do comportamento de um edifício na fase de utilização é necessário compreender que existe uma cadeia de relações entre os seus diferentes elementos constituintes. No entanto, para a análise da durabilidade em geral, torna-se útil a identificação isolada dos mesmos, como núcleos independentes de degradação que contribuem em conjunto para a maior ou menor durabilidade da construção. Assim, à semelhança de critérios definidos em análises à modelação do comportamento de edifícios em serviço (Rodrigues, 2003), procurou-se no contexto do presente trabalho, referenciar alguns dos elementos normalmente constituintes dos mesmos com importância para a aplicação prática de um plano de inspeção e manutenção e que carecem de cuidados de manutenção ao longo da sua vida útil (Tabela 1 - pág. 33, pt. 2.2.). Esta subdivisão pode ainda vir a incluir outros elementos aqui não referenciados, dependendo das características de cada edifício.

Aplicação do PIMEC aos elementos

Após a caracterização geral do edifício (estágio A.A.), o planeamento da manutenção com o PIMEC inclui um grande número de procedimentos e ações. A segunda fase, que é a mais importante e complexa para a aplicação prática do plano, consiste em três etapas fundamentais, tal como se evidencia na Figura 1 (Figura 1 - pág. 32, pt. 2.2.). A primeira, é a caracterização pormenorizada da composição dos elementos primários - designação 2.B., nomeadamente com a sua descrição e/ou materiais constituintes (B.A.). Depois, procede-se à caracterização do comportamento em serviço (3.C.), com a organização do manual. Com a Caracterização do Estado de Referência - CER (3.C.B.) (Figura 2 - pág. 33, pt. 2.2.), procura-se conhecer a situação atual do elemento, sobretudo analisando o nível de degradação que o mesmo apresenta. Para tal, recorre-se à realização de inspeções (C.B.1.) e posteriormente faz-se o registo do resultado das mesmas por elemento (D.B.2.), utilizando por exemplo um modelo pré-concebido para relatório de inspeção.

Procedimentos de inspeção e manutenção correntes

A etapa final consiste em analisar os procedimentos de inspeção e manutenção correntes (4.), passíveis de aplicação, nomeadamente com o planeamento da manutenção (4.D.). Para tal, critica-se cada tipo de ação (ou conjunto de ações) de manutenção cuja realização se exige durante a vida útil do elemento, caracterizando os respetivos parâmetros que confiram fiabilidade às diversas estratégias arbitradas. Por exemplo, no caso da manutenção preventiva (Figura 3 - pág. 34, pt. 2.2.), estuda-se a caracterização dos parâmetros envolvidos (D.A.1.), como a previsão da vida útil, níveis de qualidade, níveis de desempenho exigidos e o registo da degradação. Posteriormente elabora-se um mapa de manutenção

preventiva, arbitrando e estudando diversas estratégias de intervenção, utilizando várias operações de manutenção, previamente definidas e orçamentadas.

Um PIMEC deve ter um carácter dinâmico o que implica a sua constante revisão e atualização, desde logo a partir da existência de novas informações ou quando for essencial adaptá-lo, sempre com o objetivo de se estabelecer uma adequada gestão de recursos e uma decisão de intervenção de acordo com as disponibilidades do orçamento.

Estudo de caso

O teste do PIMEC foi realizado em quatro edifícios da Universidade de Coimbra (Figura 4 - pág. 35, pt. 2.2.) cuja área de fachadas (mais de 37.000 m2) está revestida com ETICS. De acordo com a configuração definida para o PIMEC, o ETICS é um elemento de revestimento de fachada (A.A.3.1), particularmente da envolvente do edifício. Todas as fachadas dos edifícios referidos foram até agora inspecionadas duas vezes para se obterem os dados essenciais necessários para abordar a CER para o ETICS, conforme definido pelo PIMEC (Tabela 2 - pág. 36, pt. 2.2.). Três grupos de patologias foram observados durante as duas inspeções: (i) defeitos superficiais, (ii) fissuras e (iii) deterioração local. A Figura 5 (pág. 37, pt. 2.2.) ilustra alguns desses defeitos. Uma noção sobre a evolução geral das principais patologias nas fachadas afetadas encontra-se na Figura 6 (pág. 39, pt. 2.2.) e na Figura 7 (pág. 39, pt. 2.2.) ilustra-se a evolução da importância relativa de cada patologia distribuída por diferentes níveis de degradação.

Planeamento da manutenção

A Figura 8 (pág. 41, pt. 2.2.) representa uma proposta de curva de degradação para o ETICS dos casos em estudo, sem qualquer ação de manutenção - também baseada em modelos similares (Flores, 2002) e simulada com um andamento de um polinómio do segundo grau, para uma taxa de degradação que vai aumentando lentamente no início (2%), sendo ligeiramente mais acelerada para o fim da vida útil (5%) – critérios estes definidos como representativos. Como resultado, é possível estimar uma vida útil de 24 anos para um desempenho mínimo de 20%. Também diversas estratégias de manutenção e os consequentes cronogramas temporais de intervenção foram simulados. Um cronograma com as sete estratégias mais económicas para o caso de manutenção preventiva está representado na Tabela 4 (pág. 42, pt. 2.2.). O critério de decisão para selecionar a estratégia mais favorável baseou-se na aplicação do método do Custo de Ciclo de Vida (LCC). Ainda na Figura 9 (pág. 43, pt. 2.2.), representa-se uma curva de degradação para um dos cenários simulados de manutenção preditiva para o ETICS, em concordância com o estabelecido no PIMEC.

Conclusões

Este trabalho de investigação produziu uma configuração para um modelo de PIMEC, tentando fazer sua análise realista num ETICS. O estabelecimento de um processo de PIMEC permite a

identificação e caracterização de todos os elementos de um edifício, com a recolha de um conjunto de informações significativas.

Com este modelo é também genericamente possível aumentar o conhecimento relativo aos parâmetros envolvidos na simulação de procedimentos de manutenção previstos, proporcionar-se a apresentação de abordagens simplificadas e um melhor entendimento da interação entre os elementos do edifício. Com o ensaio prático do planeamento da manutenção de acordo com as diferentes perspetivas de ações previstas pelo PIMEC, foi possível ensaiar modelações teóricas de manutenção aplicadas ao ETICS e fornecer uma perspetiva do que poderá ser o seu comportamento a longo prazo.

O aspeto provavelmente mais importante a retirar desta análise, aponta para que qualquer que seja o tipo de manutenção do revestimento, a sua realização permite obter resultados teóricos de durabilidade bastante bons. Neste caso, para um ETICS, a durabilidade pode duplicar se, em condições controladas, existirem cuidados de manutenção análogos aos propostos. A configuração apresentada para o PIMEC pretendeu ser, naquela fase, um modelo discutível, no sentido de se vir a encontrar uma solução melhor e mais eficaz.

Desenvolvimento de uma aplicação abrangente para a gestão integrada da manutenção de edifícios

O capítulo 3 abrange da terceira até à sétima contribuição, sendo que as três primeiras são fundamentalmente de revisão bibliográfica. Aqui inclui-se então um estudo bibliométrico para avaliação dos progressos gerais no conhecimento em ME, uma breve revisão bibliográfica sobre diversos modelos, sistemas e métodos para GM e uma abordagem conceitual à aplicação do conceito Lean na GME.

Posteriormente, são expostos os preceitos base e as linhas gerais do SIAPME e é ainda apresentada, em termos gerais, a adaptação computadorizada testada para uma das seis Funções Gerais de Gestão do Património previstas pelo modelo referido.

Estudo de avaliação dos progressos gerais do conhecimento em manutenção de edifícios

Introdução

Em resultado de uma detalhada revisão bibliográfica, este ponto apresenta uma apreciação geral sobre uma área importante do conhecimento em constante evolução como é a ME,

expondo-se os resultados estatísticos relativos a um levantamento de mais de dois mil e duzentos títulos de publicações, agrupados em seis indicadores bibliográficos predefinidos. O trabalho teve por base vários estudos, diversas pesquisas e uma sistematização bibliográfica cobrindo diferentes aspetos. Para o efeito, foram identificados vários tipos de contribuições técnico-científicas para se poder ter uma perceção da sua evolução quantitativa e qualitativa, bem como do seu desempenho, tendo sido possível esboçar um modelo aproximado de crescimento geral da literatura. Com a identificação dos subtemas dessas publicações foi possível ainda efetuar uma revisão crítica no sentido de ter uma perceção sobre potenciais lacunas no progresso do conhecimento (subáreas de investigação, que podem ainda exigir maior desenvolvimento) bem como de indagar a importância da linha de investigação exposta nesta tese. As informações reunidas periodicamente foram ordenadas e analisadas sob diferentes perspetivas. A realização deste diagnóstico seguiu um procedimento metodológico. O trabalho de pesquisa bibliométrica envolveu algumas etapas pré-estabelecidas e foi restringido por determinadas limitações à frente abordadas. Segue-se uma breve síntese de resultados parciais para alguns indicadores alvo (chamados Indicadores Diretos) e as características mais importantes resultantes da avaliação global são posteriormente discutidas por forma a estimar um modelo de crescimento aproximado da literatura. Com base na metodologia utilizada, uma visão geral de algumas subáreas de pesquisa também é apresentada, o que pode ainda requer desenvolvimentos adicionais posteriores. Esta abordagem parece ter sido pioneira quando comparada com outros estudos conhecidos na área de ME.

Estágios da metodologia de pesquisa

Dependendo dos objetivos, foi então necessário estabelecer os limites para o corpo da análise empírica. Isto conduz a adotar procedimentos metodológicos próprios e por isso se decidiu agrupar os principias indicadores e designá-los por Indicadores Diretos e Indicadores Resultantes. Os Indicadores Diretos estão associados a cinco indicadores alvo e pré-selecionados a partir da produção científica e literária comum, ou seja, aos seguintes géneros ou conjuntos de publicações: Livros, Artigos em Revistas, Artigos em Eventos (ambos do tipo académico, técnico ou profissional), Teses & Dissertações e Normas. Foi ainda considerado um grupo suplementar, denominado Outros Documentos, de forma a incluírem-se uma série de elementos dispersos, aos quais muitas vezes é atribuída menor importância ou associada falta de conhecimento sobre a sua existência. Os Indicadores Resultantes são diretamente relacionados com cada Indicador Direto e representam vários aspetos que resultam do tratamento numérico e estatístico da pesquisa. Estes podem ser o número de títulos encontrados, a sua distribuição temporal, a ocorrência de palavras ou expressões (relacionados diretamente ou de interesse comum ao tema da ME), países, idiomas, autores, eventos (considerados agrupados com diversos casos como congressos, conferências, seminários, workshops, entre outros), etc. A Tabela 1 (pág. 54, pt. 3.1.) resume a correlação entre alguns destes indicadores.

Também é importante referir quais foram os pressupostos básicos do estudo (tipo, tempo e espaço) e os principais meios ou campos de pesquisa utilizados (suportes). A pesquisa e a recolha de dados relativos a cada Indicador Direto focou-se sobretudo no levantamento de todos títulos possíveis identificados como já publicados, que envolvessem interesse académico (ou intrínseco) para o estudo do tema da ME e associados a um contexto de utilidade para um hipotético gestor da atividade de GME. Deve notar-se que um título geralmente anuncia a principal informação existente num texto ou identifica os elementos que caracterizam o respetivo conteúdo (Ferreira, 2002).

Os resultados da pesquisa foram sendo gradualmente organizados num banco de dados (catálogo) para cada Indicador Direto. Para o posterior processo de cálculo e análise estatística, recorreu-se às capacidades do MS Excel.

Deste modo, foi possível estabelecer e apresentar uma perspetiva de alguns de entre muitos resultados parciais obtidos (para Indicador Direto e Indicadores Resultantes correlacionados), discutir determinados aspetos relevantes e no final realizar uma análise abrangente e conclusiva.

Síntese dos resultados parciais

Com este estudo obteve-se um conjunto enorme de resultados. Por exemplo pode apresentar-se os resultados parciais da pesquisa relativos a Livros - disponibilidade por década (em percentagem do total (Figura 1 - pág. 56, pt. 3.1.); relativa à soma dos Artigos em Eventos por década (Figura 2 - pág. 56, pt. 3.1.), etc.

Resultados globais - modelo hipotético de evolução da literatura

O tratamento integral dos resultados parciais permitiu obter interessantes indicadores globais de comportamento e ter uma visão mais abrangente do estudo, principalmente a fim de estimar um modelo de crescimento aproximado da literatura neste campo, com particular interesse para a GME. Portanto, no total, esta investigação envolveu cerca de 2250 títulos de publicações com importância, provenientes de seis Indicadores Diretos, com uma determinada distribuição temporal (Figura 3 - pág. 58, pt. 3.1.).

Ainda no que se refere à contribuição para a melhoria da agenda de investigação e no caso de se pretender ter uma ideia sobre o potencial de oportunidade do tipo de trabalho académico aqui apresentado, tornou-se necessário identificar e analisar dados de saída que pudessem fornecer indicações nesse sentido. Assim, admitiu-se utilizar um método simples, como a análise da frequência de ocorrência em todos os títulos de palavras ou expressões específicas, intimamente relacionadas com o âmbito em estudo e que poderão retratar uma gama de questões de investigação mais ou menos estudadas. Neste contexto, a Figura 5 (pág. 60, pt. 3.1.) apresenta, por exemplo, a taxa de incidência de um conjunto de 35 expressões usadas na amostra global de títulos em Inglês, verificando-se que de uma forma geral, as

expressões com maior incidência nos títulos recolhidos são ‘maintenance management’, ‘building maintenance’ e ‘facilities management’ e os três primeiros grupos de expressões incluem palavras como 'maintenance' (ou ‘repairs’ e ‘conservation') e ‘manage(ment)’, representando quase dois terços do número total dessas ocorrências.

O grupo de expressões em torno dos subtemas relacionados com a manutenção computadorizada tem uma razão de ocorrência de quase 5%, sendo que este pode muito bem representar um dos assuntos de maior interesse nos últimos tempos, com potencial para aumentar. Estas conclusões fazem assim presumir que a linha de orientação do estudo aqui exposto se enquadra num campo de pesquisa que pode ser prioritário e estar associada a uma oportunidade com potencial sucesso de exploração.

Conclusões

Tanto os resultados parciais como os resultados globais alcançados parecem ter alguma consistência e afiançar uma boa precisão da amostra, apesar de eventuais pequenos erros ou problemas associados que podem sempre ser apontados em estudos semelhantes. A primeira ideia a ser destacada, relativa ao grupo de Indicadores Diretos e ao seu tratamento composto, é que existe um constante aumento do número de publicações ao longo do tempo, refletindo assim uma crescente atenção em torno do tema da ME em geral. Neste contexto, a língua mais usada é o Inglês e a maioria das publicações encontradas têm origem anglo-saxônica (Reino Unido e Estados Unidos da América – EUA). Além disso, parece haver uma tendência crescente para publicar trabalhos científicos em Inglês, com o objetivo de lhes dar maior visibilidade e globalizar o conhecimento.

Por fim, com o conjunto de resultados globais foi possível obter-se um modelo de crescimento aproximado da literatura e, ao mesmo tempo, terem-se algumas indicações sobre possíveis lacunas no desenvolvimento do conhecimento. Em suma, com este estudo foi possível atualizar o conhecimento geral acerca dos principais indicadores bibliográficos diretamente relacionados com a ME e de particular interesse para a GME e prestar um contributo interessante e talvez diferente no sentido de caracterizar o estado da arte.

Mais detalhes sobre este assunto constam também do documento de compilação de estudo individual (Falorca, 2017) disponível online em: http://bit.ly/JF-GME-CE (Cap. 3, pág. 43) e ainda em Falorca, Rodrigues e Silva (2012).

Modelos e sistemas de gestão da manutenção – uma revisão para introduzir um sistema de informação abrangente para edifícios

Introdução

Este estudo resume uma revisão bibliográfica sobre diversos modelos, sistemas e métodos de GM, tanto aqueles com origem e aplicação na indústria em geral, quanto os mais importantes

já desenvolvidos e aplicados em edificações e conjuntos construídos. O principal objetivo desta análise foi reunir as informações disponíveis, identificar os avanços no conhecimento e tentar trazer para o funcionamento do SIAPME muitos destes fundamentos.

Abordagens no campo da manutenção industrial

Esta etapa do estudo consistiu basicamente na identificação e análise, em grande parte da literatura, de diversos modelos e procedimentos, os quais, em geral, foram estudados, desenvolvidos e / ou utilizados com sucesso na área de manutenção industrial. Deve notar-se que a organização industrial é um sistema aberto, no qual as matérias-primas são transformadas em produtos acabados com valor agregado. Neste contexto, a função de manutenção visa garantir a integridade dos ativos fixos, particularmente na perspetiva de garantir a função operacional dos equipamentos. Portanto, permanecem a experiência, as revisões do equipamento e as recomendações do fabricante como fatores determinantes em relação ao tipo e frequência das operações de manutenção. É também importante notar que a manutenção industrial é bastante dedicada a sistemas dinâmicos, nos quais o movimento é um fator chave de seu comportamento, enquanto a ME lida com sistemas estáticos, cujo desempenho é altamente dependente de fenômenos de envelhecimento e muito menos de esforços dinâmicos.

A estrutura dessa análise não se isenta, por exemplo, de fazer uma referência à World Class Maintenance (WCM). Assim, a necessidade de se estabelecerem parâmetros como meio de comparação entre empresas (Benchmarking), particularmente visando ocupar o lugar entre os melhores do mundo, levou à introdução do termo WCM. Está integrado no âmbito da World Class Manufacturing, para descrever um modelo que era novo, diferente e eficaz para a função de manutenção. Estabelecendo-se como uma capacidade estratégica de competir através da gestão integrada de ativos, o WCM visa alcançar um alto grau de competitividade em sua área de atuação e permite às empresas competir em qualquer mercado internacional, utilizando alguns recursos-chave como o Sistema Informatizado de Gestão, a Melhoria Operacional, Manutenção Centrada na Confiabilidade (RCM), Manutenção Produtiva Total (TPM), Melhoria Contínua e Manutenção Preventiva e Preditiva.

Abordagens no campo dos edifícios

Numa segunda fase da revisão bibliográfica, analisou-se uma ampla gama de métodos e outros procedimentos desenvolvidos e/ou utilizados (ou mesmo com potencial interesse) no campo de edifícios, infraestruturas ou conjuntos construídos. A Figura 1 (pág. 70, pt. 3.2.) mostra o âmbito genérico das situações mais relevantes. Neste ponto, foi analisado, por exemplo, conceito de Physical Asset Management (PAM – ou Gestão de Ativos Físicos) para as organizações, sendo que nas normas do tipo PAS - Public Available Specification – ou Especificação Pública Disponível (BS PAS 55-1, 2008), a definição de Asset Management é a seguinte: “Conjunto de atividades e práticas sistemáticas e coordenadas, através das quais

uma organização gere os seus ativos e sistemas de ativos de forma otimizada e sustentável, assim como o seu desempenho, riscos e custos associados, ao longo dos seus ciclos de vida tendo como objetivo alcançar o seu plano estratégico organizacional". Foram também analisados diversos casos de diretrizes para sistemas de GME, Sistemas de Gestão da Manutenção (SGM) para conjuntos edificados e métodos de avaliação do estado de conservação de edifícios, entre alguns outros.

Discussão e conclusões

O interesse de ir à indústria buscar noções diversas e conhecer os seus constantes progressos, prende-se com o facto de existirem muitos aspetos com grande potencial de adaptação aos SGM de edifícios, sendo certo que nos últimos anos já há investigadores que os têm considerado nos seus projetos de desenvolvimento, apesar de muitas vezes esse desiderato ainda ser concretizado de forma ténue ou experimentalista. Como à manutenção industrial interessa sobretudo a salvaguarda das peças e dos equipamentos de forma a garantir o seu bom funcionamento e, assim, se produzirem os produtos com a máxima rentabilidade, também no caso dos edifícios interessa preservar os seus diversos elementos construtivos, através de métodos operacionais profícuos, para se obter a máxima longevidade, em conjugação com o bem-estar dos seus utilizadores. A manutenção industrial utiliza técnicas que estão em constante mutação por força de um contínuo investimento no seu desenvolvimento, sendo que muitas delas são já bastante avançadas. Desta forma, pode ser vantajoso, para quem se debruce sobre o assunto da ME, reter algum domínio nesse campo e porventura aplicar o conhecimento daí adveniente (na medida das necessárias adaptações), sobretudo quando se estudam formas de idealizar modelos de manutenção integrados, facilmente aplicáveis, independentemente da dimensão do edifício ou do conjunto de edifícios, e que confiram simultaneamente a máxima utilidade, no contexto das necessidades atuais de preservação, tanto aos gestores de parques edificados, de condomínios, etc., como até ao comum utilizador. De uma análise global e mais alargada como a que foi realizada, é viável retirar diversas conclusões e fixar muitos aspetos de grande utilidade; contudo, salientam-se aqui apenas os possíveis, por força da dimensão e do conteúdo genérico deste texto. Ainda assim, pôde verificar-se que, no caso da indústria e ao nível das empresas mais exigentes, a manutenção já segue padrões de topo, designados de Classe Mundial, em que se faz o uso generalizado de diversos meios, como os Sistemas Computadorizados de Gestão da Manutenção (SCGM), a Melhoria Contínua, entre outros. Um dado transversal a todo este sector de atividade tem sido a opção crescente e generalizada pela utilização da manutenção preventiva.

Mais detalhes sobre estes temas constam ainda do documento de compilação de estudo individual (Falorca, 2017) disponível online em: http://bit.ly/JF-GME-CE (Cap. 4, pág. 65 e Cap. 5, pág. 151) e de uma revisão da literatura mais recente (pág. 101 a pág. 107, pt. 3.4.).

Manutenção de edifícios Lean – proposta para uma abordagem conceptual

Introdução

Este estudo de carácter puramente teórico, procurou, em primeiro lugar, esclarecer o que representam os princípios Lean, como é que eles têm sido utilizados recentemente e os seus principais objetivos. Além disso, procurou-se descobrir como podemos introduzir e usá-los na fase de GME, e por fim, verificar que tipo de uso prático e utilitário pode ser retirado destas teorias. Com isso em mente, foi incluída uma visão geral sobre o conceito Lean, focando pontos-chave do estado da arte que possam ter interesse de aplicabilidade no aperfeiçoamento de processos envolvidos ou a desenvolver para uma GME adequada. A análise do ponto de situação atual não dispensou uma pesquisa refletiva sobre os mais recentes princípios em utilização no sector da construção, com origem na filosofia Lean. Esta abordagem é fundamental para se poder entender melhor os diferentes aspetos que podem ser úteis para a sua aplicabilidade dentro do campo da GME. Desta forma, a questão em pesquisa será então situada, não descurando os avanços que têm tido lugar recentemente na Construção Lean (Lean Construction - LC), principalmente no que diz respeito a algumas ferramentas introduzidas e ao conhecimento empírico mais relevante, entretanto desenvolvido. Ainda com o intuito de se prever uma base sólida de utilização do conceito Lean, foi idealizada e apresentada uma aplicação prática com o objetivo de integrar os conceitos mais importantes identificados e considerados como adaptáveis a um denominado e possivelmente regular Processo de Gestão da Manutenção de Edifícios (PGME). Neste âmbito, com base no conhecimento empírico adquirido, são listados os principais problemas relacionados com o desperdício e, por fim, é apresentada uma proposta conceptual para a integração do conceito Lean na fase de longo prazo de uma construção comum.

Do ponto de vista científico-metodológico, este estudo é fundamentalmente visto como uma pesquisa teórica, em que o conhecimento reunido foi usado para formular uma aplicação prática, com o intuito de ajudar a resolver os problemas atuais da vida moderna.

Posicionamento da questão em análise

Lean é uma filosofia a partir da qual foram desenvolvidos métodos, técnicas e ferramentas. Pela definição da palavra anglo-saxónica, ser Lean baseia-se em ser magro, rápido e ágil. Pelo que um sistema Lean é encarado sinteticamente como um sistema eficiente e em permanente estado evolutivo. Em português, a palavra significa magro (sem gordura), ou seja, tenta refletir o facto de, numa fábrica, se utilizar metade do esforço humano, metade do espaço de manufatura, metade do investimento em manufatura e ferramentas e metade do tempo em engenharia, desenho e desenvolvimento de um novo produto. A filosofia Lean já está a ser aplicada nas mais diferentes áreas, como em companhias aéreas, na restauração, na saúde, etc., sendo que o sector da construção também não é exceção. Neste contexto, há que situar

a questão em análise e como tal não se pode separar do tema da construção em geral, apesar de se reconhecer que o sector é complexo e diversificado, abrangendo muitos agentes atuando em etapas distintas de um empreendimento (Picchi, 2000). Assim, tendo em conta os diversos agentes intervenientes na execução do empreendimento, adotou-se a nomenclatura proposta por Picchi (2003), cujos fluxos para o sector da construção estão representados na Figura 1 (pág. 86, pt. 3.3.).

Construção Lean (Lean Construction)

Ao tentar posicionar a questão em estudo é também indispensável uma abordagem à área específica da LC, uma vez que este assunto tem reunido crescente interesse e investigação por parte da comunidade científica e pode ajudar a fazer um melhor enquadramento do problema em análise. Assim, a LC pode ser uma forma de projetar e construir baseada na Lean Production, para maximizar o valor e minimizar o desperdício, encontrando ao mesmo tempo o equilíbrio entre tempo, custo e qualidade no sector da construção (Ballard, 2000). Um breve exame a diversa literatura sobre a LC, permitiu ainda perceber que a maioria dos estudos consistem em abordagens empíricas e dispersam-se por diversas matérias sobre as quais tem recaído o recente debate na LC - embora tal análise tenha sido, apesar de tudo, relevante para uma melhor compreensão acerca da questão aqui em discussão. Por isso, com um sentido de recolher perspetivas ainda mais úteis, a Tabela 1 (pág. 88, pt. 3.3.) apresenta um breve panorama do âmbito e dos resultados de alguns casos importantes que abrangem um conjunto de aspetos em discussão na LC nos últimos anos. Juntamente com a importância que esta análise da literatura traz para uma maior compreensão sobre a questão em pesquisa, serviu também para ilustrar uma certa dispersão de matérias nas quais se tem centrado o recente debate em torno da LC.

Desenvolvimentos recentes visando o período de longo prazo dos edifícios

Para além da aplicação da temática Lean à fase de construção de edifícios (sobretudo focada na LC), persiste ainda alguma dificuldade em encontrarem-se trabalhos direcionados. Porém, é de assinalar que uma tese desenvolvida por Salermo (2005) já fez uma aplicação concreta de ferramentas do Lean Thinking e da manutenção autónoma aos serviços de manutenção. Na Tabela 2 (pág. 89, pt. 3.3.) procura-se resumir alguns aspetos desta adaptação. para a utilização das ferramentas Lean à fase de ME. Ao longo do desenvolvimento do presente estudo tentaram-se ainda encontrar outros estudos nos quais se aplicassem ou analisassem os aspetos Lean ao fluxo de uso e manutenção, mas tal não foi bem-sucedido. Isto pode levar a concluir que esta questão em concreto parece ainda encontrar-se numa de desenvolvimento. E, de facto, esta proposta de integração pode também assim ser vista como uma pesquisa exploratória.

Proposta de introdução das práticas Lean à fase de uso e manutenção

Para caracterizar em geral um PGME, há que determinar primeiramente um quadro de referência para estabelecer uma aplicação, a qual, à partida, deverá incidir sobre as relações entre os diversos intervenientes normalmente em funções num fluxo de utilização e manutenção. Então, prevê-se que a implementação daquilo a que aqui se chamou de PGME (ou em inglês: Building Maintenance Management Process - BMMP) irá, na generalidade envolver entidades e pessoas com diferentes funções, diferentes métodos e diferentes atividades e fazer uso de um programa informático para apoiar e coordenar. Na realidade, repare-se que este género de atividade de gestão é normalmente realizado por uma vasta gama de empresas diferenciadas a trabalhar neste mercado específico. Genericamente, elas podem oferecer serviços aos "Clientes" (por exemplo os proprietários) os quais, por sua vez, precisam satisfazer certos requisitos relativos aos seus bens. Há muitos casos em que essa interação é integrada, ou seja, por exemplo, no caso em que o proprietário tem na sua estrutura de funcionamento interno um departamento direcionado para a manutenção. De qualquer forma, a empresa de GME ou o seu departamento poderá coordenar outras entidades, tais como "Fornecedores", "Parceiros Externos" e até integrar ou não um "Armazém" de fornecimento de materiais. A função de manutenção é, então, teoricamente, implementada através de um "Sistema Organizado de Gestão", com base em conceitos fundamentais ("Itens de Gestão") e envolvendo os diversos e essenciais "Indicadores de Gestão da Manutenção". Para auxiliar todo este processo, os recursos são integrados e centralizados, por exemplo, num CMMS - conforme representado em esquema na Figura 2 (pág. 90, pt. 3.3.).

Com base na organização genérica de um PGME e atentos às principais causas de desperdício identificadas, materializa-se neste ponto uma proposta para integração conceitual dos princípios Lean à fase de ME. Esta proposta é basicamente sustentada em diferentes perspetivas extraídas da revisão da literatura atrás feita, consideradas com particular relevância para esse contexto. Assim, com o exercício apresentado na Tabela 3 (pág. 92, pt. 3.3.) julga-se estar lançado um conjunto de novas ideias em torno do Pensamento Lean, às quais se decidiu simplesmente chamar "Manutenção de Edifícios Lean" (ou seja, em Inglês: Lean Buinding Maintenance - LBM).

Discussão e conclusões

O Pensamento Lean destaca a identificação e eliminação de desperdício e ao mesmo tempo a maximização de valor ao longo de um processo de trabalho. O âmbito de utilização do conceito Lean à GME pode incluir diversas oportunidades de aplicação não exploradas até ao momento. Este estudo em particular, tentou estabelecer um pequeno exercício de sistematização do conhecimento Lean, indo desde as suas origens até às aplicações mais recentes e que podem ter potencial de utilização no tema da ME. A revisão realizada pretende constituir-se como uma contribuição original para o conhecimento Lean aplicável à

GME e facultar outro recurso valioso para os investigadores nesta área, influenciando assim o alargamento das fronteiras do debate, sobretudo no contexto do sector da construção. As implicações da pesquisa foram direcionadas principalmente para a necessidade de reexaminar e melhorar a utilização de práticas de gestão na fase de ME, fundamentalmente com a preocupação de eliminar os desperdícios mais comuns. Desta forma, a utilização de ferramentas Lean pode representar muitos desafios para as práticas atuais na GME. Algumas das complexidades envolvidas na implementação dos seus procedimentos estão normalmente relacionados com a inadequação dos sistemas de gestão tradicionais. No entanto, existem apenas alguns (poucos) trabalhos de investigação conhecidos orientados para a identificação dos potenciais campos de melhoria.

Acredita-se que os investigadores que estudem assuntos em torno da filosofia Lean devem ser estimulados a não limitarem as suas pesquisas apenas a uma fase específica da construção, mas sim de acordo com uma plataforma mais ampla que inclua a GME, de modo que essa extensão possa também beneficiar mais da investigação Lean. A globalidade da análise realizada e constante deste estudo parece constituir-se como um valioso contributo para a utilização do conhecimento em torno da filosofia Lean. E acima de tudo, este conhecimento pode ou deve ser revigorado, tanto nas necessidades de atualização de ferramentas de software existentes para GME, bem como no desenvolvimento de novas aplicações. Um exemplo disto está também já no esforço da sua abrangência/previsão na modulação de um sistema de informação conforme é o caso do SIAPME.

Mais detalhes sobre o desenvolvimento deste assunto constam também do documento de compilação de estudo individual (Falorca, 2017) disponível online em: http://bit.ly/JF-GME-CE (Cap. 6, pág. 333).

Principais funções para a gestão da manutenção de edifícios: uma aplicação por estrutura de funções

Introdução

Neste estudo apresenta-se um algoritmo de procedimentos para a GME (genericamente denominado SIAPME), o qual pretende ser uma contribuição adicional para otimizar as práticas de gestão numa estrutura de ME. Este estudo surge então no sentido de se poderem melhorar os métodos de gestão de ativos imobiliários, com base num cuidadoso planeamento de processos e atividades. Pelo que só através do desenvolvimento de mais investigação e de diretrizes cientificamente fundamentadas, se alcança plenamente esse objetivo. Foi assim delineado um modelo de sistema de informações gerenciais, com o objetivo de ser realizado em um formato legível por computador e, assim, visto como um facilitador do desempenho funcional de qualquer organização, independente do seu porte e da carteira patrimonial em questão. Este modelo tem um conjunto de princípios orientadores e estratégias sustentáveis e

acredita-se que seja mais promissor, se adotar uma base de design inovadora, mais abrangente e integradora de todas as informações.

Aspetos da revisão da literatura

A revisão da literatura aqui exposta, incidiu principalmente sobre dois pontos (pág. 101 a pág. 107, pt. 3.4.). O primeiro diz respeito a uma análise (mais atualizada) sobre modelos e sistemas de gestão de manutenção no âmbito dos edifícios. O segundo ponto abrange o enquadramento das TICs, abrangendo, por um lado, as tendências tecnológicas de suporte à GME, por outro, as aplicações computadorizadas e o software, bem como ainda aspetos relacionados com o crescente envolvimento do modelo Building Information Model (BIM) e a fase de utilização dos edifícios.

Modelos e sistemas de gestão de manutenção no âmbito dos edifícios

Neste âmbito, ressalva-se que as entidades responsáveis pela GME devem estabelecer as políticas e as estratégias de manutenção, definir os processos, as atividades e os recursos para atender às expectativas dos utilizadores e garantir a qualidade do serviço de manutenção prestado. Contudo, para atingir esse objetivo, verifica-se que os sistemas ou os modelos utilizados têm geralmente abordagens diferenciadas que dependem de várias circunstâncias. Ao longo desta pesquisa bibliográfica encontrou-se um conjunto de publicações, como normas, guias, estudos académicos e outros, focados em diferentes utilizações, como sejam habitação, escolas, universidades, hospitais, etc.

Enquadramento das TICs e tendências tecnológicas de suporte à GME

Há autores (Taillandier et al., 2011) que reconhecem duas abordagens principais para a realização de planos de manutenção - a abordagem automatizada assistida por computador e a abordagem operacional. De fato, uma ampla análise aos progressos alcançados nas últimas décadas na utilização de computadores e no desenvolvimento de softwares específicos para ME, permite concluir que a introdução de computadores e de softwares personalizados melhora substancialmente a capacidade dos gestores dos ativos físicos em coletar, monitorizar e avaliar dados, assim como também ao nível da tomada de decisões estratégicas, relativamente ao nível de serviço requerido.

Na década de 1990, os chamados SCGM (ou Computerised Maintenance Management System - CMMS) tornaram-se populares, cobrindo algumas atividades como a monitorização financeira, o agendamento de manutenção e os levantamentos do estado de conservação dos edifícios e de outros ativos. Outros autores (Ismail e Kasim, 2013) observaram que a utilização de TICs na ME é principalmente em três áreas das Tecnologias da Informação (TI): os sistemas baseados (Sistemas de Gestão de Edifícios - Building Management Systems ou BMS); o software em geral (processadores de texto, folhas de cálculo, gestão de projetos, AutoCAD); e os bancos de

dados (bancos de dados com medidores de leituras, bases de dados com pormenores das solicitações de manutenção e outros).

Atualmente estão disponíveis numerosos SGM que utilizam sistemas baseados em TI para substituir sistemas antigos que usavam métodos convencionais. O aplicativo CMMS surgiu do desenvolvimento de sistemas baseados em TI, sendo atualmente amplamente utilizado em processos de GM para instalações de edifícios. No entanto, neste nível, há outras aplicações, como o CAFM (Gestão de Instalações Assistida por Computador), o IWMS (Integrated Workplace Management System - Sistema Integrado de Gestão dos Locais de Trabalho) e o FMIS (Facility Management Information System - Sistema de Informação de Gestão de Instalações).

Também já existem várias tecnologias emergentes que são importantes no desenvolvimento dos sistemas de gestão de instalações da próxima geração: os Sistemas de Comunicação Sem Fio (Wireless Communication Systems), Serviços Web (Web Services), as Agent Technologies, o Contexto Computacional (Context-Aware Computing), as Redes de Sensores Sem Fio (Wireless Sensor Networks) e as Tecnologias de Marcação (Tagging Technologies). Outros progressos têm sido alcançados e os SGM também estão a utilizar a Identificação por Radiofrequência (RFID - Radio Frequency Identification), os Testes não Destrutivos (NDT), Sensores, etc.

Aplicações computadorizadas e o software

Quanto às aplicações computadorizadas - nos últimos anos, imensas ferramentas de software foram desenvolvidas, geralmente de natureza comercial, havendo outras desenvolvidas para utilização privada ou ainda até resultantes de projetos de investigação, etc. Uma vez que existe uma gama tão ampla de exemplos, uma análise sobre este assunto poderia ser exaustiva para ser abordada neste contexto. Fazendo uma pesquisa na Internet, vários sites podem ser encontrados, descrevendo inúmeras opções de software disponíveis, cada uma com suas próprias peculiaridades. Através de um breve exame às principais características de alguns programas, percebe-se que eles podem cobrir uma variedade de áreas como seja a GM, a gestão de ativos, a gestão de carteiras imobiliárias, etc. No entanto, parece que as perspetivas de desenvolvimento por detrás do software comercial são muito baseadas numa competição de negócios do dia-a-dia, possibilitando uma adaptação para cada setor de atividade de acordo com uma filosofia de 'módulos' disponíveis e flexíveis.

O crescente envolvimento do BIM e a fase de utilização dos edifícios

Ainda no que respeita ao crescente envolvimento do BIM, verifica-se que nas últimas décadas, o setor de construção tem mostrado um crescente interesse no uso destas ferramentas, uma vez que podem trazer benefícios e economia de recursos durante as fases de planeamento, projeto e construção de novos edifícios. E aqui a questão põe-se pelo fato de haver uma discussão com um significado renovado devido à suposição de que as informações do BIM coletadas durante o ciclo de vida de uma instalação poderiam ajudar a melhorar a eficiência

de gestão do ativo em causa. Ou seja, parece que, sendo uma tecnologia em rápido desenvolvimento, o BIM apresenta potencial na solução de problemas em todas as fases, inclusive na fase de Operação e Manutenção (O&M). A revisão bibliográfica feita neste campo permitiu também verificar que o tópico BIM na gestão de instalações (Facilities Management – FM) tem-se tornado um importante assunto objeto de estudo. Muitas contribuições têm estado a surgir, investigando o valor e os desafios do BIM, não apenas no contexto da FM, mas também já com foco na GME. Desta forma, foi possível verificar que a utilização do BIM na fase de O&M dos edifícios poderá trazer vantagens, ter limitações e alguns desafios associados. Quanto às vantagens, há quem admita que a integração da GME no BIM poderá eventualmente aumentar a eficiência do processo de manutenção, mas por outro lado, embora existam tecnologias comercialmente disponíveis para a transferência de dados entre modelos BIM e sistemas de gestão de instalações, o processo pode não ser direto ou económico.

Portanto, a falta de interoperabilidade entre sistemas de software pode constituir uma das limitações que explicam por que razão o potencial do BIM nas fases de O&M dos edifícios ainda não foi completamente utilizado. Assim, os desafios atuais residem sobretudo na necessidade de melhores práticas para que se desenvolvam as estratégias de transferência de dados.

Mais detalhes sobre o assunto das TICs no apoio à GM constam também do documento de compilação de estudo individual (Falorca, 2017) disponível online em: http://bit.ly/JF-GME-CE (Cap. 8, p. 383) e em Falorca, Rodrigues e Silva (2011).

Principais características do algoritmo do SIAPME

Neste ponto faz-se referência à extensão funcional do SIAPME, ao Gestor Geral (GG), às Funções Gerais de Gestão do Património e ainda à possibilidade de Informação Integrada.

Extensão funcional do SIAPME

Pretende-se que o SIAPME agregue como base funcional a interação de quatro sectores de entidades, a saber:

i). a Gestão (que inclui a Administração Geral do património a gerir). Neste âmbito existem ainda três entidades fundamentais que são o GG, os Serviços Internos Gerais e os Serviços Operacionais;
ii). o Património que é gerido pela área da Gestão e pode ser descriminado/identificado em um (ou vários) Edifícios ou alternativamente em um (ou vários) Conjuntos Patrimoniais (CP's);
iii). o Outsourcing, que no fundo inclui todos os Serviços Externos necessários à gestão do património em geral e pode ser descriminado em uma (ou várias) Empresas, Fornecedores de Serviços e/ou Prestadores de Serviços;

iv). A Interação - a designação desta entidade deve-se ao facto de se pretender incluir e fazer participar no âmbito da manutenção os principais beneficiados com a mesma e que são o(s) Utilizador(es) do património e por inerência também o(s) Utilizador(es) do sistema.

A Figura 2 (pág. 109, pt. 3.4.) é uma representação esquemática da amplitude deste modelo. Através da Tabela 1 (pág. 128, pt. 3.5.) também se pode ter outra perspetiva da extensão do modelo.

O Gestor Geral

O GG irá interagir com o Outsourcing e todos os Utilizadores, através do próprio SIAPME. Portanto, o Gestor Geral ocupa-se da chamada Gestão Geral, cujo campo de ação se conecta a uma janela intrínseca (Figura 3 - pág. 110, pt. 3.4.). No total, existem seis linhas principais que o GG deve seguir e tentar cumprir ao longo das suas funções. Assim, ao clicar em:

- Níveis de Gestão – refere-se a uma área informativa que em termos genéricos abrange o nível estratégico, o nível tático e o nível operacional;
- Gestão com Classe - faz ligação a uma área de verificação e controlo de aspetos básicos que se aplicam no modelo WCM.
- Ciclo de Melhoria Continua - há ligação a uma área informativa para confirmação e controlo constante de aspetos relacionados com a Estratégia, os Recursos, a Operação, a Revisão e o Desenvolvimento Contínuo.
- Benchmarking da Organização - surge uma área com diversos níveis, abrangendo os Requisitos do Processo de Benchmarking, o Tipo de Benchmarking utilizado e as Etapas do Processo de Benchmarking.
- Manutenção de Edifícios Lean (LBM) - a respetiva janela aborda as interações que devem existir no PGME e nos fluxos da LBM.
- Instalações Sustentáveis – liga a um campo periférico para lidar com este assunto.

Há também uma opção de Recursos Bibliográficos, dando total acesso a um catálogo. Neste caso, os registos são formados provisoriamente por um conjunto de ficheiros interligados de entensão .xls.

Funções Gerais de Gestão do Património

Clicando em Funções, o utilizador tem acesso ao que é considerado o núcleo do SIAPME, intitulado de Funções Gerais de Gestão do Património. Algumas dessas funções são indicadas na parte inferior da Figura 3 (pág. 110, pt. 3.4.) e na Figura 4 (pág. 75, pt. 3.2.), abrangendo o Controlo, os Recursos de Suporte, os Bens Imobiliários, a Manutenção Operacional, a Exploração e a Atualização & Valorização. Por exemplo, ao nível da Manutenção Operacional é imprescindível fazer-se o Controlo das Atividades ao nível Técnico e Económico, sobretudo da Execução da Manutenção (com base nas Ordens de Trabalho - OT - previstas) e através de

um Balanço. A Figura 4 (pág. 111, pt. 3.4.) mostra uma configuração possível para o nível de Opções Estratégicas no caso de equipamentos mecânicos, como elevadores e escadas rolantes (um pouco de acordo com a legislação portuguesa), que por sua vez é parte de um Plano Geral de Rotina de Utilização. A Figura 6 (pág. 135, pt. 3.5.) representa também uma Opção Estratégica para paredes exteriores, no caso de Manutenção Preventiva.

Também a subfunção de Gestão Técnica, Inteligente e Centralizada (GTIC) inserida na função de Exploração, pretende conseguir centralizar toda a gestão das áreas mais técnicas em funcionamento num edifício ou CP (independentemente da sua dimensão), tendo assim prevista ligação a dez áreas diferentes, tais como a Gestão de Energia, o Controlo de AVAC, de Iluminação, Utilitários, Segurança, os Meios Digitais, Motores, Eficiência Energética, Conforto e Sustentabilidade e os Recursos Renováveis. Os objetivos principais são sobretudo monitorizar, medir e otimizar todos os recursos existentes, por forma a tornar a gestão global mais sustentável do ponto de vista económico, técnico e social. Por exemplo, na Figura 5 (pág. 112, pt. 3.4.) demonstra-se o que se pretende abranger com os campos da Gestão de Energia e do Conforto e Sustentabilidade. Prevê-se ainda que a GTIC tenha ligação a Instruções de Utilização das Instalações & Equipamentos, com várias subopções, incluindo por exemplo Ligações, através da Internet, a vários simuladores de Água, Energia, a Manuais de Eficiência Energética, Segurança Contra Incêndios, etc. Existem ainda as opções de análise da Centralização e Tratamento de Informação e do Histórico do Funcionamento de todos os sistemas, bem como dos seus Custos de Funcionamento, Análise de Indicadores de Qualidade de vários itens e Avaliação e Certificação da Sustentabilidade em Edifícios.

Informação Integrada

No essencial, a Informação Integrada consiste em ter disponível um Histórico sobre cada Elemento do Edifício (EE) e sobre cada edifício, reunindo neste caso todas as informações acumuladas sobre os mesmos e também outras provenientes de diversas origens, necessárias a este intuito. Tenta-se exprimir a ideia sobre este campo de forma gráfica através da Figura 6 (pág. 113, pt. 3.4.). Esta opção terá duas áreas nas quais se pode clicar. Caso se pretenda ter a Informação Integrada sobre determinado EE, há que o procurar na lista disponível (ou selecioná-los noutras zonas do programa onde o mesmo esteja disponível ou visível – por exemplo sobre o projeto, etc.). Ao selecioná-lo, pretende-se que surja um cronograma temporal com um conjunto de informações sobre o mesmo. Este cronograma terá então assinalado a data atual, a data de aplicação do EE no edifício (ou data de entrada em funcionamento) e todas as Ações de Manutenção (AM) de que o mesmo foi alvo, com a respetiva data e os dados relacionados, tais como o Tipo de Ação de Manutenção, a respetiva Descrição, a Informação sobre o Nível de Qualidade, os Custos e se a intervenção em causa resulta ou não de uma Anomalia Imprevista. Na circunstância de o EE em análise ser já um Caso de Substituição, surge uma outra janela com o mesmo tipo de informação atrás mencionada. Em alternativa, na eventualidade de se ter como alvo a recolha ou observação

da Informação Integrada sobre um edifício, seleciona-se o mesmo e surgirá neste caso, uma tabela na qual estão assinalados todas as AM por cada ano e as referências aos EE distribuídas pelos quatro grandes grupos considerados neste trabalho (EE, Instalações e Equipamentos, Espaços Exteriores e Outros). O que se pretende, é que passando por cima de cada AM surjam os respetivos dados, conforme atrás referidos. Na parte inferior da tabela, prevê-se que surja um gráfico de colunas com o número anual acumulado de AM's bem como com o valor do custo de manutenção anual acumulado.

Análise crítica comparativa e pontos fortes e pontos fracos

Para verificar os aspetos mais importantes da convergência do projeto SIAPME em relação a uma ampla gama de assuntos revisados, foi realizado um exame crítico comparativo. O objetivo é demonstrar que o algoritmo proposto é uma solução abrangente e, de fato, que ele efetivamente cobre uma boa parte de assuntos fundamentais. Portanto, o estudo examinou pontos de correspondência com aspetos da teoria da ME e com outros modelos, procedimentos, guias, normas e assim por diante, principalmente desenvolvidos e/ou aplicados a edifícios, conforme já visto anteriormente. De fato, em todas as comparações, uma ampla gama de pontos de concordância foi registada com sucesso. Usando exemplos simples, o modelo está alinhado com normas relevantes, como a BS 8210 (2012), é consistente com a possibilidade de abranger uma ampla gama de tipos de instalações e com a utilização de TIC, etc. Os procedimentos do SIAPME também incluem a necessidade de integrar Indicadores-Chave de Desempenho (KPI) de forma semelhante à sugerida por Silva, (2010) e Shohet e Nobili (2017). O campo do modelo referente à Informação Descritiva do Edifício (folha com os Dados Gerais do Edifício) está planeado para ter em consideração métodos como MAEC - Método de Avaliação do Estado de Conservação de Imóveis (Pedro et al., 2008; Vilhena, 2011) e as características gerais do SIAPME parecem estar em conformidade com as linhas de orientação para uma estrutura de GM, conforme recomendado pelo QDHPW (2018).

Também foi realizada uma síntese de pontos fortes e fracos do modelo SIAPME. Assim, as vantagens mais importantes podem ser compiladas da seguinte forma: a) uma eventual conversão numa solução de software permitirá a separação em módulos básicos para gerenciamento mais personalizado de um edifício ou de um portfólio de edifícios ou para ser adaptado às necessidades específicas do gestor de manutenção; b) permitirá uma demarcação clara e detalhada das funções e diretrizes do gestor, definindo uma ampla gama de aspetos que geralmente não são considerados noutras soluções; c) será possível aos gestores definir estratégias e medir e controlar seu próprio desempenho; d) irá prever o(s) balanço(s) para cada atividade; e) o SIAPME permitirá o controlo total de todos os EE, através das Árvores de Cadastro/Atributos; f) também fornecerá mecanismos automáticos para reação e operacionalização das inspeções de manutenção; g) abrangerá todos os edifícios, através da gestão da Alocação de Espaços e de uma detalhada GTIC. Uma desvantagem relevante pode estar relacionada com a natureza inovadora de alguns aspetos que, na medida em que nunca

se materializaram e foram aplicados na prática, podem criar dificuldades à sua posterior operacionalização.

Conclusões

Neste caso de estudo apresentou-se a abrangência de uma investigação cujo objetivo foi delinear um algoritmo de procedimentos, considerado essencial para as principais funções de GE. A abordagem metodológica caracteriza-se essencialmente por duas fases principais: (1) revisão do estado da arte, em que se fez uma pesquisa abrangente sobre diferentes perspetivas teóricas; e (2) o desenvolvimento de um modelo de sistema genericamente chamado de SIAPME.

Em relação aos principais aspetos da revisão da literatura, foram discutidas algumas abordagens importantes dentro do contexto dos modelos e sistemas com interesse no campo dos edifícios, bem como diferentes questões no contexto das TICs. Focando as tendências tecnológicas para apoiar a GME em geral, realizou-se um breve relato bibliográfico, abordando-se depois, outras considerações sobre aplicações computadorizadas e software. Ainda sob esta agenda, o BIM foi considerado uma área de crescente investigação e desenvolvimento. Uma análise introspetiva foi descrita, principalmente no sentido de compreender o crescente envolvimento do BIM na fase de utilização dos edifícios, bem como o potencial de compatibilidade do SIAPME.

Também são apresentadas as principais características do SIAPME, resumindo a sua extensão funcional, o papel do GG e destacando certas linhas de ação. Para verificar aspetos importantes de concordância entre o modelo e as várias questões analisadas, foi feita uma análise crítica comparativa, apenas apresentada em termos gerais. No entanto, verificaram-se resultados promissores.

O ambicioso objetivo do SIAPME é servir como uma base estratégica bem fundamentada para o desenvolvimento de uma solução de software com identidade própria. Com base num design inovador e uma integração abrangente de informações, este modelo é considerado viável. Um importante objetivo subjacente foi encontrar uma estrutura de procedimentos que possibilitasse a simplificação do desempenho funcional de qualquer organização, independentemente de seu tamanho. Por outro lado, o algoritmo também pretende aproveitar a utilização de um conjunto de novas tecnologias para suportar suas funções. Mesmo a partir do entendimento da atual etapa do desenvolvimento do BIM ao longo do ciclo de vida dos edifícios, acredita-se que as características do modelo SIAPME possam ser compatíveis com esta ferramenta. Assim, ao considerá-lo como um instrumento válido, desenvolvimentos mais importantes podem ainda ser alcançados, particularmente na fase de ME.

Esta investigação também permitiu entender que muitas das questões-chave do conhecimento atual ainda não foram totalmente trazidas para o projeto e operacionalização dos sistemas de informação, principalmente daqueles mais voltados para o espectro da ME. Esta questão é sentida mais fortemente ao nível dos métodos típicos desenvolvidos para o campo industrial, que poderiam ser úteis em desenvolvimentos posteriores e que, é claro, só terão efeito depois que os ajustes necessários sejam introduzidos.

Embora em termos práticos, o algoritmo SIAPME ainda carece de uma validação empírica, o que será um processo algo demorado, algumas iniciativas iniciaram-se já nesse sentido (conforme a seguir se expõe).

Portanto, de forma abrangente, esta investigação pretende contribuir para o desenvolvimento do conhecimento, principalmente por meio de uma proposta que visa otimizar os múltiplos aspetos envolvidos no campo da GM. Em alguns países do Sul da Europa, como Portugal, a aplicação de estratégias como as estudadas, pode ter um impacto significativo, particularmente em termos económicos e sociais bem como numa mudança de paradigma na forma como um edifício em serviço é visto.

O SIAPME é ainda descrito detalhadamente no documento de compilação de estudo individual (Falorca, 2017) disponível online em: http://bit.ly/JF-GME-CE (Cap. 9, pág. 443).

Uma abordagem integrada à função de recursos de suporte de um sistema de informação para gestão de manutenção de edifícios

Introdução

A implementação das operações de ME e a sua gestão logística exigem a otimização de todos os recursos relacionados. Tal envolve grande potencial, se forem utilizadas metodologias cientificamente fundamentadas, juntamente com meios informatizados, permitindo assim uma integração total da informação. Os Recursos de Suporte são uma das seis principais funções de gestão previstas no algoritmo de procedimentos do SIAPME e a sua importância é fundamental para o sucesso da abordagem proposta pelo mesmo. Como primeiro resultado prático do modelo elaborado, apresentam-se as principais diretrizes para a referida função, que, entretanto, foi introduzida numa plataforma de software desenvolvida para o efeito. Os resultados obtidos com este ensaio, fornecem evidências acerca das potencialidades do SIAPME, particularmente no que diz respeito à eficácia dos próprios procedimentos e a uma integração adequada de todas as informações necessárias gerir. Ou seja, a ideia geral é mostrar que tanto o trabalho definido para a ME como aquele que é decorrente de seu controlo de atividade, somente será extremamente eficiente se a gestão de todos os Recursos

de Suporte for realizada com base num sistema muito bem organizado, fornecendo as informações corretas acerca de todos os envolvidos e acerca de todos os componentes.

A função de Recursos de Suporte

Uma vez que o estudo em particular recaiu sobre a função de Recursos de Suporte, neste ponto é apresenta uma breve descrição da mesma, não se fazendo outra ou maior introspeção aos procedimentos em geral do modelo SIAPME, uma vez que já foi sucintamente realizada.

Portanto, a gestão geral de um património requer a necessidade de controlar e conhecer em tempo real todos os recursos a si afetos e os que são utilizados para esse desígnio. Na função Recursos de Suporte (esquematizada ao fundo da Figura 1 - pág. 129, pt. 3.5.) abrange-se a gestão dos Meios como os Materiais, os Recursos Humanos, os Equipamentos entre outros; a gestão da Organização através do seu Organigrama Funcional, Procedimentos Operacionais, etc.; e as TIC's, particularmente no que diz respeito à Gestão de Funcionamento do SIAPME, incluindo toda a logística relativa ao hardware e software que venha a estar envolvido.

Os Meios utilizados na gestão geral do património

O algoritmo do SIAPME compreende a subfunção referida como Meios, que no fundo se trata de um cadastro, que se subdivide em:

- Gestão de Recursos Humanos - com um registo de todos os recursos humanos necessários para o trabalho de gestão dos diferentes ativos;
- Gestão de Materiais - a gestão do conhecimento sobre o cadastro de Materiais e Equipamentos (incluindo os processos de Aquisição, a árvore de materiais e equipamentos, etc.);
- Gestão de Recursos Humanos – incluindo quem são os Gestor(es) Geral(ais) de Nível 0 e 1, os Serviços Internos Gerais de Nível 2 e 3 e os Serviços Operacionais de Nível 3 que são necessários para o trabalho de gestão dos diferentes ativos;
- Gestão de Utilizadores do SIAPME – relativo aos Utilizadores Gerais e Utilizadores Reconhecidos;
- Gestão de Outsoursing – inclui o registo e gestão de todas as partes interessadas no processo de outsourcing: as Empresas, os Fornecedores de Serviços e os Prestadores de Serviços;
- Gestão de Recursos Bibliográficos;
- Indicadores de Desempenho dos Meios;
- Geração de Relatórios.

Neste caso, também será possível obter uma conexão com a árvore de todos os EE, principalmente através da gestão de Códigos, já que cada um possui sua própria identificação.

Na Figura 4 (pág. 133, pt. 3.5.), as diferentes opções aqui descritas já surgem como uma parte importante da adaptação experimental informatizada do SIAPME.

A Organização

Na função Organização gere-se o Organigrama Funcional e as respetivas Dependências Hierárquicas da entidade que faz a gestão (por exemplo por Níveis Estratégicos).

São também previstos envolver os Procedimentos Operacionais e a Definição de Modelos Tipo de Documentação que toda a estrutura de gestão do património pode gerar e fazer circular.

As TIC's no SIAPME

Aqui julgou-se importante ter em consideração a Gestão do Funcionamento do próprio sistema, quando a funcionar plenamente num suporte informático. Esta gestão incide sobretudo:

- Nos Processos, na Atualização e na Inovação do seu software;
- Num Plano de Manutenção do Sistema;
- No cadastro das Infraestruturas existentes e dos Equipamentos utilizados na Organização;
- Na Gestão dos Níveis de Utilização;
- Na Gestão de Informação;
- Na Integração de Modelos Tipo de Documentação.

Introdução da adaptação informatizada experimental do SIAPME

Apenas para fins de estudo e investigação, foi desenvolvida uma pequena adaptação experimental computadorizada para o algoritmo do SIAPME, utilizando para fase inicial a programação em Visual Basic. Assim, o processo de Login é realizado com base na categoria do utilizador, de acordo com a terceira coluna da Tabela 1 (pág. 128, pt. 3.5.). Este procedimento é iniciado através da exibição de uma janela na qual os diferentes tipos de utilizadores são diferenciados (Figura 2 - pág. 131, pt. 3.5.). Dependendo da situação, uma segunda janela aparecerá, na qual pode ser selecionado o Nome do Utilizador e inserido o Código de Identificação ou uma Senha. Se o utilizador for identificado corretamente, esta etapa termina com uma mensagem de boas-vindas. Deve notar-se que o Login só pode ser feito com suporte num banco de dados de utilizadores previamente estabelecidos (este sistema de registo é descrito mais adiante).

A janela inicial e a janela com as informações básicas sobre a primeira versão desta adaptação (denominada Versão 1.0.2017) são exibidas na Figura 3 (pág. 132, pt. 3.5.). Também pode ser verificado que as principais opções de conexão coincidem com os procedimentos estabelecidos no algoritmo pré-estabelecido, como é patente na Figura 1 (pág. 129, pt. 3.5.). Por exemplo, ao clicar na opção de Ajuda, é permitido revisitar todo o

algoritmo, ainda no formato original (como um conjunto de organogramas interconectados em folhas do MS Excel).

Conforme ilustrado na Figura 3 (pág. 132, pt. 3.5.) e na Figura 4 (pág. 133, pt. 3.5.), seguindo a ordem de opções como Gestão → Funções → Recursos de Suporte → Meios, a respetiva janela surgirá (Gestão de Meios). A janela referente aos Meios, permite assim ao utilizador, aceder às diferentes opções de gestão previstas para todos os recursos utilizados na ME, conforme atrás exposto. Portanto, é possível fazer o registro de todos os elementos relacionados com generalidade dos recursos humanos envolvidos, bem como aqueles referentes a equipamentos, materiais, agentes de outsourcing, etc. Em sentido contrário, é possível fazer uma pesquisa por todo o programa, para se poder ter uma visão sobre as informações de registo de cada recurso, fazer alterações e assim por diante.

Todos os recursos utilizados, incluindo Materiais, Equipamentos e EE, terão um código de identificação (ID) ao qual pode ser associado um código de barras ou um código QR. Além disso, prevê-se que ao registarem-se, seja ainda atribuído a todos os utilizadores do SIAPME um código de acesso ou autorização. Portanto, clicando no botão Gerar Código ID, uma janela adicional é exibida, com a possibilidade de gerar Senhas Aleatórias, Códigos de Barras e Códigos QR. Outras opções também permitem salvar a imagem do código gerado, e até mesmo lê-lo, por exemplo, através da Webcam do computador que esteja a ser utilizado. Para se ter uma ideia sobre estes procedimentos, a Figura 5 (pág. 133, pt. 3.5.) mostra as janelas projetadas para tal. Os dados cadastrais de cada utilizador estarão completos se todos os dados pessoais estiverem associados. Para tal, ao clicar no botão Associar Outros Dados (Figura 4 - pág. 133, pt. 3.5.), surge uma nova janela e será possível preencher múltiplos campos, como a data de nascimento, local de nascimento, endereço, números de telefone, etc.

A informação de Recursos de Suporte integrada dentro da Manutenção Operacional

Todas as informações armazenadas da maneira descrita acima para a função Recursos de Suporte podem, assim, ser usadas de maneira integrada no contexto da Manutenção Operacional. Especificamente, o algoritmo do SIAPME prevê que a ME será feita através do Planeamento Estratégico da Manutenção, pelo Gestão de Recursos de Manutenção e pela Gestão Económica de Manutenção. Por outro lado, o Controlo das Atividades de manutenção será essencialmente realizado com base nas OT previstas e em outras situações complementares. Um dos aspetos mais importantes a considerar neste contexto refere-se ao fato de que o Planeamento Estratégico de Manutenção será baseado na definição e cumprimento, para cada EE, de um Plano Estratégico da Manutenção (PEM), principalmente através da realização de um conjunto de Opções Estratégicas de manutenção. A Figura 6 (pág. 135, pt. 3.5.) exemplifica para o caso de paredes exteriores (que eventualmente podem

abranger as soluções de revestimento mais comuns). Portanto, como é possível inferir a partir deste enquadramento, tanto o trabalho definido em cada Opções Estratégicas de manutenção para cada EE, quanto aquele decorrente da manutenção do Controlo das Atividades, somente será o mais proficiente se a gestão de todos os Recursos de Suporte estiver em consonância com uma abordagem baseada numa organização bem estruturada.

Conclusões

A GME exige a utilização de meios que garantam a eficácia absoluta de seus procedimentos, aliados à satisfação de diferentes metas de sustentabilidade. Neste estudo faz-se a apresentação de determinadas linhas do modelo de procedimentos do SIAPME, particularmente daquelas relacionadas com a sua função de Recursos de Suporte. Simultaneamente, alguns aspetos da adaptação experimental computadorizada são descritos em geral. Resultante desta abordagem, algumas conclusões podem ser tiradas. Em primeiro lugar, as características básicas do modelo esboçado parecem estar em convergência com os diferentes tipos de modelos atuais, possivelmente até com aqueles posicionados nas categorias CAFM e CMMS. Além disso, esta pesquisa permite constituir-se como uma contribuição valiosa para uma discussão mais aprofundada sobre a identificação e correção de lacunas para muitos sistemas atualmente em uso. Por fim, através dos procedimentos estabelecidos para o SIAPME, qualquer gestor de edificações poderá ter uma perspetiva muito ampla de suas funções, cobrindo quase todos os aspetos fundamentais para uma manutenção mais eficiente e integrada, com ótimo controlo de todos os participantes deste processo.

Principais conclusões

A consideração de metodologias de manutenção no âmbito da GE deve fazer parte integrante de todas as fases de um processo de um empreendimento, por forma a obter-se um sistema integrado, com informações base, que possam ainda ser úteis em casos futuros. Devem também considerar-se três tipos de gestão dos edifícios: a Gestão Técnica, a Gestão Económica e a Gestão Funcional ou Social. Em toda esta perspetiva, é necessário conhecer a teoria das estratégias da manutenção e correlacionar as diferentes questões intrínsecas.

Com o estabelecimento de um processo de PIMEC foi possível identificar e caracterizar os principais elementos de um edifício, por meio da recolha de um conjunto de informações significativas sobre os mesmos. Com este modelo foi também genericamente possível aumentar o conhecimento relativo aos parâmetros envolvidos na simulação de vários procedimentos de manutenção, facilitando a apresentação de abordagens simplificadas e um melhor entendimento da interação entre os elementos do edifício. Mediante um ensaio prático do planeamento da manutenção de acordo com as diferentes perspetivas de ações previstas pelo modelo PIMEC, foi então possível ensaiar modelações teóricas de manutenção

aplicadas a um revestimento do tipo ETICS, dando assim uma perspetiva do que poderá ser o seu comportamento a longo prazo - que se julga ser bastante promissor em termos de durabilidade, independentemente do tipo estratégias de manutenção que se proponham. Obviamente, o formato apresentado para um PIMEC pretendeu ser um modelo discutível, que contribuiu para que se encontrasse uma solução melhor e mais eficaz para a GME.

É nesse sentido (não descurando parte do conhecimento adveniente do PIMEC) que se desenvolveu posteriormente o SIAPME. Assim, a consumação desse objetivo teve por base, primeiramente, um conjunto de etapas de revisão bibliográfica.

Com este trabalho em particular, pretendeu-se essencialmente aprofundar ainda mais os conhecimentos sobre a temática da ME e formular uma hipótese de base científica.

Assim, por exemplo, com a investigação bibliométrica foi possível avaliar em pormenor os progressos ocorridos em vertentes do conhecimento com interesse para a GM, obter-se um modelo de crescimento aproximado da literatura e, ao mesmo tempo, terem-se algumas indicações sobre possíveis lacunas. Tratou-se assim, de um contributo interessante e talvez diferente no sentido de caracterizar o estado da arte.

Por outro lado, estudaram-se ainda um conjunto de modelos e SGM aplicados tanto no sector industrial como nos edifícios. Neste desiderato, o interesse de ir, por exemplo, à indústria, buscar noções diversas e conhecer os seus constantes progressos, deve-se ao facto de existirem muitos aspetos com grande potencial de adaptação aos SGM de edifícios, tanto que nos últimos anos já há investigadores que os têm considerado nos seus projetos de desenvolvimento. Verificou-se que a manutenção industrial utiliza técnicas que estão em constante mutação por força de um contínuo investimento no seu desenvolvimento, sendo que muitas delas são já bastante avançadas. Pelo que se considerou que poderia ser vantajoso reter algum conhecimento nesse campo e porventura aplicá-lo (na medida das necessárias adaptações e possibilidades) - principalmente quando se estudam formas de idealizar modelos de manutenção integrados, facilmente aplicáveis, independentemente da dimensão do edifício ou do conjunto de edifícios, e que confiram simultaneamente a máxima utilidade, no contexto das necessidades atuais de preservação, tanto aos gestores de parques edificados, de condomínios, etc., como até ao comum utilizador.

Por exemplo, a Terotecnologia foi o primeiro conjunto das práticas de GM que evidenciou a importância da análise integrada do custo do ciclo de vida dos equipamentos (LCC), objetivando assim a sua minimização. O seu modelo básico pretende dar aos projetistas o feedback das informações geradas nos diferentes estágios do ciclo de vida do bem a manter. Também a WCM se afirmou como uma capacidade estratégica de competição através da gestão integrada dos ativos. O seu principal objetivo é atingir um alto grau de competitividade na área de atuação e capacitar as empresas para a concorrência em qualquer

mercado internacional, utilizando como principais recursos um SCGM, o melhoramento operacional, a RCM, a TPM, a melhoria contínua, a manutenção preventiva e preditiva e seguindo ainda os seis níveis de evolução até à manutenção pró-ativa. Por seu lado, o Benchmarking é um dos aspetos a considerar mais importantes para a melhoria do desempenho. Permite uma comparação das melhores práticas recorrendo às melhores empresas, possibilitando também assim ter conhecimento dos pontos fortes e fracos dos seus processos, das novas ideias e incorporá-las.

Do estudo geral destes métodos, conclui-se que os mesmos são extremamente importantes e abrangem muitos objetivos e procedimentos que podem ter grande utilidade numa perspetiva da GME. Ou seja, sobretudo em termos da utilização dos seus conceitos gerais (se vistos porventura de forma superficial) ou da transposição pormenorizada das suas técnicas (se vistos de uma forma mais incisiva) - neste último caso implica mais estudo e investigação para que essa ligação possa ser a mais perfeita possível.

No caso dos métodos desenvolvidos ou já aplicáveis em concreto aos edifícios foi também possível retirar algumas conclusões interessantes. Por exemplo é muito comum surgir, de certa forma associado ou relacionado com a ME, os termos FM e a PAM. No primeiro caso, pode genericamente referir-se como sendo uma atividade profissional de gestão do património e dos serviços de apoio à atividade de uma organização, tratando-se de uma disciplina em crescente expansão e ainda não muito difundida em Portugal de uma forma estruturada, mas com grande potencial de crescimento relativamente ao que se tem verificado noutros países. A bibliografia indica que a FM permite a gestão de quatro dos principais recursos de uma organização como são os recursos financeiros, humanos, os ativos fixos (património construído e equipamentos) e os recursos relativos à informação e ao conhecimento. Além disso, caso se considere fazer uma divisão da gestão de uma organização em três áreas distintas (gestão estratégica, gestão tática e gestão operacional), a FM poder-se-ia aplicar a cada uma delas, embora com uma abrangência diferente.

Já no caso da PAM, o respetivo conceito tem tido recentemente associado um grande interesse e desenvolvimento, tendo surgido inclusivamente um conjunto de especificações (as normas do tipo PAS 55) que permitiram definir mais adequadamente o contexto atual do Asset Management e o seu domínio de aplicação. No fundo, a definição mais atual está muito ligada a atividades e práticas que se requerem sistemáticas e coordenadas, através das quais uma organização faz a gestão dos seus ativos (de forma mais otimizada e sustentável), do seu desempenho, dos riscos e dos custos associados, para que com tudo isto consiga satisfazer plenamente o respetivo plano estratégico organizacional.

Ainda do estudo detalhado dos componentes dos sistemas de GME, inferiu-se que estão disponíveis alguns documentos normativos muito recentes, que dispõem de excelentes diretivas para o planeamento, gestão e controlo da ME e dos seus ativos. Além disso,

verificou-se, por exemplo, que o DHPW ou "Departamento de Habitação e Obras Públicas" do estado de Queensland na Austrália, também tem uma série de documentos muito úteis para servirem de guia à definição de novos modelos e de estratégias para a gestão da atividade de manutenção.

Assim, genericamente, um SGM deve seguir as seguintes grandes linhas principais: (i) o planeamento e desenvolvimento da manutenção; (ii) incluir os diversos aspetos intrínsecos à execução da manutenção; e (iii) considerar os sistemas informatizados de gestão da manutenção.

Também têm sido desenvolvidos, por diversas entidades e investigadores, importantes indicadores de desempenho específicos para a manutenção, normalmente utilizados durante a revisão do SGM, como forma de verificação e avaliação do seu funcionamento. Para a análise dos sistemas existentes ou desenvolvidos em concreto para GM de conjuntos edificados, estudaram-se ainda vários casos nacionais e estrangeiros. Neste último caso, há sobretudo a destacar o exemplo da gestão do património edificado da Universidade de Savoie que se baseia num conjunto muito abrangente de atividades.

Apesar das diferenças em termos de pormenor, todas as situações analisadas têm sempre por linhas mestras o levantamento da condição, a priorização, o planeamento da manutenção, a orçamentação e a execução dos trabalhos. Também se verificou que em alguns destes métodos já se aplicaram aspetos relacionados com a gestão de risco e com o desempenho.

Embora o mapeamento destes exemplos da atividade de gestão do património tenha uma pendente basicamente teórica, o reconhecimento das respetivas estruturas organizacionais pode servir de referência a outras entidades gestoras de património edificado e ao mesmo tempo servir como guião para o desenvolvimento de aplicações que permitam um controlo mais eficaz da informação.

Por último, constatou-se ainda existir uma larga gama de métodos relacionados com a avaliação do estado de conservação, fruto de muita e boa investigação feita tanto a nível nacional como internacional e envolvendo em muitos casos, o interesse público nessa matéria. Em quase todos os métodos desenvolvidos, verificou-se que é quase sempre comum aos mesmos o respetivo âmbito (em geral abrangem as habitações) e o recurso à inspeção visual como forma de avaliação utilizada.

Portanto, no cômputo geral deste estudo em particular, ficou evidente já existir uma grande diversidade de aplicações e estudos de enorme interesse para a GME. Também se verificou um crescente aparecimento de políticas muito apropriadas e exigentes da implementação de Sistema de Gestão da Manutenção de Edifícios - SGME (sobretudo nos casos desenvolvidos no

domínio anglo-saxónico e francófono), algumas orientações normativas de grande qualidade e alguns exemplos resultantes de uma boa investigação académica.

Do estudo feito ao conceito Lean, pôde concluir-se que os princípios da filosofia Lean Thinking constituem um "roadmap" para a sua implementação nas organizações (incluindo as que se dedicam à manutenção), sobretudo no sentido de introduzir uma cultura de melhoria contínua. Portanto, numa organização Lean, todos devem estar decididos em identificar e suprimir as fontes de desperdício e de ineficiências.

A partir do que se considerou ser um 'PGME' - no qual se julga hipoteticamente que todos os recursos são integrados e centralizados, por exemplo, num sistema informático - projetaram-se um conjunto de possíveis interações entre os diversos agentes envolvidos; e atento às algumas causas de desperdício que podem surgir na fase de utilização e manutenção, constituíram-se as linhas base para a respetiva integração dos princípios Lean, julgando então assim estar lançado um conjunto de novas ideias em torno do Pensamento Lean, às quais se decidiu simplesmente chamar "Manutenção de Edifícios Lean". O seu objetivo principal centrou-se sobretudo na necessidade de estimular a agilização de procedimentos.

Também foi possível constatar que ao nível da Lean Maintenance e da LC, têm surgido alguns progressos interessantes, cujos fundamentos poderão contribuir igualmente para o desenvolvimento de novas teorias ou aplicações.

Considerando os novos desafios em contextualização, destacaram-se ainda a importância de alguns aspetos relacionados com aplicações tecnológicas de apoio à GM. Constatou-se, por exemplo, que desde há cerca de duas décadas se tem registado um grande progresso e aperfeiçoamento ao nível TIC, adaptadas à FM ou à GME. E quanto à sua abrangência aos elementos construtivos, faltam ainda aplicações que possibilitem uma utilização flexível e fundamentada em modelos ou suportes cientificamente testados, embora no estrangeiro, há já um conjunto mais alargado de soluções para a gestão e manutenção de infraestruturas, contudo muitas delas evidenciam ainda certas limitações ao nível desta particularidade. Também a introdução de computadores e de software personalizado melhoraram substancialmente a capacidade dos gestores de instalações em cumprir aspetos da manutenção relacionados com recolha sistemática, monitorização e aferição de dados e as tomadas de decisão estratégicas em relação ao nível de manutenção necessária.

Concluiu-se ainda que os dois tipos de software mais conhecidos relativos à FM ou ME são os CAFM e os CMMS. Em geral, estes tipos de softwares suportam as atividades de FM com aplicações para gestão de ativos, GM, gestão de carteiras de imóveis, gestão dos espaços, sustentabilidade ambiental, etc.

Portanto, sem um sistema de informação eficaz pode não ser totalmente possível aos gestores de edifícios e instalações garantir a sua completa manutenção. Como o controlo da informação é um dos aspetos de gradual importância nas sociedades modernas, qualquer organização dedicada à manutenção não deverá dispensar o uso dos meios mais adequados para a sua recolha, armazenamento, processamento, representação e distribuição, minimizando desta forma o esforço requerido por tais preocupações. O que implica que a utilização de sistemas de informação para GME é um importante facto a ter em consideração.

No caso do BIM, há presentemente uma grande discussão devido à suposição de que as informações do BIM reunidas durante o ciclo de vida de uma instalação poderiam ajudar a melhorar a eficiência de gestão do ativo em causa. Ou seja, parece que, sendo uma tecnologia em rápido desenvolvimento, o BIM apresenta potencial na solução de problemas em todas as fases, inclusive na fase de O&M. A revisão bibliográfica feita neste campo permitiu também verificar que o tópico BIM na gestão de instalações FM tem-se tornado um importante assunto objeto de estudo.

Da mesma forma, a utilização do BIM na fase de O&M dos edifícios poderá trazer vantagens, ter limitações e alguns desafios associados. Quanto às vantagens, a integração da GME no BIM poderá eventualmente aumentar a eficiência do processo de manutenção, mas no que se refere à transferência de dados entre modelos BIM e sistemas de gestão de instalações, o processo pode não ser direto ou económico. A falta de interoperabilidade entre sistemas de software pode constituir uma das limitações que explicam por que razão o potencial do BIM nas fases de O&M dos edifícios ainda não foi completamente utilizado. Portanto, os desafios atuais residem sobretudo na necessidade de melhores práticas para que se desenvolvam as estratégias de transferência de dados.

Com o tratamento e a assimilação do conhecimento previamente estruturado, idealizou-se então um conjunto de linhas gerais para um denominado SIAPME. Assim, deste trabalho, conclui-se que:

- Os sistemas de informação direcionados para a GM devem ter como base funcional a interação dos principais sectores de atividades que são a Gestão Geral, o próprio Património (componentes físicas), o Outsourcing que inclui todos os serviços externos e a interação para fazer participar o(s) Utilizador(es) do património e por inerência também o(s) Utilizador(es) do próprio sistema, que no fundo são todas as entidades atrás mencionadas. Na interação da Gestão Geral com o património e o sistema, encontra-se normalmente uma Organização;
- Deve sempre existir a figura do Gestor Geral que informa e interage com a gestão de topo ou a Organização e coordena todos os sectores de atividade e respetivos intervenientes, sendo por isso, uma função muito ampla e vasta para a qual o mesmo deve estar devidamente preparado;

- A figura de Gestor Geral deverá ter sempre subjacente algumas linhas de orientação, como uma boa perceção dos níveis de gestão, fazer uma gestão de classe superior, ter sempre presente o ciclo de Melhoria Contínua, realizar tarefas periódicas de Benchmarking, ter em conta as práticas Lean e trabalhar sempre com o objetivo de ter instalações sustentáveis.

As Funções Gerais de Gestão do Património devem sempre abranger pelo menos o Controlo de toda a atividade, a gestão dos Recursos de Suporte e dos bens imobiliários, proceder à Manutenção Operacional, considerar os muitos aspetos da Exploração do património e fazer a Atualização e Valorização do mesmo.

Também se considera que qualquer sistema destinado a GME deve ter sempre por base um conhecimento empírico e teórico próximo (ou preferencialmente até mais abrangente) daquele estudado, analisado e descrito neste documento.

Portanto, é possível afirmar-se que após um eventual processo de transformação de um sistema como o proposto (SIAPME) em software, o mesmo poderá ter características transversais às consideradas nas classificações dos sistemas CAFM e CMMS, cobrindo praticamente todos os aspetos das suas categorias de aplicação como sejam a GM.

Além disso, um sistema informático, com um algoritmo igual ao que foi projetado, cobrirá um vasto conjunto de aspetos que em geral não são tidos em atenção na maioria dos sistemas ou programas existentes ou comercializados.

É ainda previsto que um exemplo concreto como o delineado, possa vir a utilizar em conjunto uma vasta gama de tecnologias mais recentes e avançadas para suporte das suas funções, como sejam o Cloud Computing, os sistemas inteligentes de telemetria, os sistemas de automação e domótica, os Wireless Communication Systems, os Sistemas de Informação Geográfica (SIG), os códigos de barras, etc.

O ensaio de adaptação informatizada experimental do SIAPME tentou confirmar alguns aspetos das conclusões atrás referidas. Ou seja, parece ter ficado demonstrado que tanto o trabalho definido para a ME como aquele que é decorrente de seu controlo de atividade, somente será extremamente eficiente se, neste caso em particular, a gestão de todos os Recursos de Suporte for realizada com base num sistema muito bem organizado, fornecendo as informações corretas acerca de todos os envolvidos e acerca de todos os componentes.

A adaptação informatizada apresentada é bastante versátil, intuitiva, dinâmica, com uma configuração simples, e ao mesmo tempo já bastante abrangente em termos dos domínios da gestão em causa. Estas caraterísticas parecem constituir-se como os alicerces para um eventual sucesso de uma futura solução informática que cobra todo o espectro de atuação do algoritmo do SIAPME.

Desenvolvimentos futuros

Sendo esta tese uma simples contribuição para a sensibilização quanto à necessidade de práticas adequadas para a gestão global dos edifícios, e considerando uma certa diversidade de 'sub-assuntos' dentro desta temática em concreto, julga-se fundamental o desenvolvimento de mais e diferentes abordagens.

Assim, referem-se alguns aspetos que poderão ser objeto de maior aprofundamento, contribuindo para o progresso e expansão da atividade de GME:

- Continuação do desenvolvimento de investigação, com base em ensaios de comportamento, de materiais em geral e de revestimentos em particular, por forma constituir-se uma base de dados cientificamente fundamentada, sobre a vida útil dos diferentes elementos dos edifícios (os mais comummente utilizados);
- Desenvolver metodologias adaptadas a cada caso, no sentido de ser possível uma melhor análise do modo de degradação dos elementos dos edifícios, como por exemplo, tipos de inspeções, técnicas a utilizar, técnicas de inspeção mais recentes, etc.;
- Elaborar uma base de dados cientificamente fundamentada com fichas de intervenção, salientando-se a importância dos pormenores mais importantes que possam garantir uma adequada durabilidade dos elementos. Nesse seguimento, proceder ainda à constituição de bases de dados sobre custos de operações (atualizáveis) de acordo com as respetivas técnicas;
- No caso particular da aplicação de ETICS, parece importante a continuação do trabalho de análise do seu comportamento em serviço, para que se aprofunde ainda mais o conhecimento sobre este sistema de revestimento e se possa também, atestar e validar (ou retificar), alguns dos procedimentos e conclusões retiradas do seu estudo através da aplicação de um PIMEC.

Aproveitando a linha de pensamento aqui expressa através da proposta de linhas gerais do SIAPME, julga-se que um dos trabalhos de desenvolvimento futuro se prende exatamente com a continuação do seu estudo e melhoramento, passando numa primeira fase, à sua adaptação a um programa informático completo (abrangendo todas as funções) e ao respetivo ensaio.

Obviamente que da multiplicidade de aspetos estudados, transparecem alguns que continuarão a merecer maior atenção, como seja por exemplo, a necessidade de maior investigação da aplicação dos princípios Lean à fase de utilização e ME.

Além disso, carece-se ainda de estudos mais aprofundados sobre como se poderão aproveitar e transpor para os edifícios, os métodos e técnicas de maior sucesso de aplicação no âmbito da manutenção industrial.

Por último, considera-se também importante alargar-se o estudo dos indicadores de desempenho às áreas do comportamento físico dos edifícios, aprofundar a introdução das metodologias de análise de risco na GM e fomentar o desenvolvimento de planos estratégicos adaptados às organizações ou entidades do sector.

Referências (do Resumo Alargado)

Abrantes, V. e Rodrigues, R. C. (1994). *Planeamento das acções de manutenção em parques habitacionais*. Comunicações do 2º ENCORE, Encontro sobre Conservação e Reabilitação de Edifícios, Vol. II, LNEC, Lisboa.

Ballard, G. (2000). *The Last Planner System of Production Control* (PhD Dissertation). School of Civil Engineering, University of Birmingham, UK.

Branco, F. (2003). *Conceber Edifícios Duráveis*. Artigo apresentado nas Palestras do 1º PATORREB, "1.º Encontro Nacional sobre Patologia e Reabilitação de Edifícios", FEUP, Porto.

BS 8210 (2012). *Guide to facilities maintenance management*. London: British Standard Institute. Informação retirada de: http://shop.bsigroup.com/ProductDetail/?pid=000000000030231187.

Cabral, J. (1998). *Organização e Gestão da Manutenção – Dos Conceitos à Prática*. Lisboa: LIDEL.

Dictionary.com (n.d.). http://dictionary.reference.com/browse/maintenance?s=t (18/07/2019).

Falorca, J. (2004). *Modelo para Plano de Inspecção e Manutenção em Edifícios Correntes* (Tese de Mestrado). FCTUC, Coimbra. Disponível em: http://bit.ly/JF-PIMEC.

Falorca, J. (2017). *Gestão da Manutenção de Edifícios - Estruturação do Conhecimento e Linhas Gerais de um Sistema de Informação para Automatização de Procedimentos*. Compilação de Estudo e de Investigação Individual, Covilhã, p. 617, Documento disponível online em: http://bit.ly/JF-GME-CE.

Falorca, J., Rodrigues, R. e Silva, R. (2011). A utilidade das aplicações informática na gestão da manutenção de edifícios. Artigo apresentado no GESCON 2011 – Fórum Internacional da Construção (Sistemas de Informação na Construção), FEUP, Porto. Disponível em: http://bit.ly/JF-UAI-GME.

Falorca, J., Rodrigues, R. e Silva, J. (2012). *Os progressos do conhecimento no campo da Manutenção de Edifícios – Estudo Bibliométrico*. Artigo apresentado no Congresso da Construção 2012, F.C.T.U.C., Coimbra.

Ferreira, N. (2002). As pesquisas denominadas "Estado da Arte". *Educação & Sociedade*, No. 79, pp. 257-272 Retirado de: http://www.scielo.br/pdf/es/v23n79/10857.pdf (18/07/2019).

Flores, I. (2002). *Estratégias de Manutenção – Elementos da Envolvente de Edifícios* (Dissertação de Mestrado). Instituto Superior Técnico, Lisboa.

Hornby, A. (2002). *Oxford Advanced Learner's Dictionary of Current English (Sixth Edition)*, Oxford University Press, p. 774.

Ismail, Z. e Kasim, N. (2013), *Implementation of information and communication technology (ICT) for building maintenance*, 1st FPTP Postgraduate Seminar 2013, Fakulti Pengurusan Teknologi dan Perniagaan, Universiti Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia, Disponível em: http://eprints.uthm.edu.my/5780/ (11 February 2019).

Natividade, E. (2002). *Avaliação do Espaço Urbano Edificado com Recurso a Tecnologias da Informação* (Tese de Mestrado). FCTUC, Coimbra.

Pedro, A., Paiva, J. e Vilhena, A. (2008), Portuguese method for building condition assessment, *Structural Survey*, Vol. 26 No. 4, pp. 322-335.

Picchi, F. (2000). *Lean Principles and the construction main flows*. Artigo apresentado na 8th Annual Conference of the International Group for Lean Construction, Brighton, UK.

Picchi, F. (2003). Oportunidades de aplicação do Lean Thinking na construção. *Ambiente Construído*, Vol. 3 No. 1, pp. 7-23.

QDHPW (2018). *Maintenance management framework. Policy for the maintenance of Queensland Government buildings*. Queensland Department of Housing and Public Works (Revised Second Edition). Australia: The State of Queensland, Disponível em: http://www.hpw.qld.gov.au/SiteCollectionDocuments/MMF.pdf (22/01/2019).

Rodrigues, R. (2003). *Gestão de Edifícios – Modelo de Simulação Técnico-económica* (Tese de Doutoramento). FEUP, Porto.

Salermo, L. (2005). *Aplicação de ferramentas da Mentalidade Enxuta e da Manutenção Autónoma aos serviços de manutenção dos sistemas prediais de água: estudo de caso: Hospital das Clínicas da UNICAMP* (Dissertação de Mestrado). Universidade Estadual de Campinas, São Paulo.

Shohet, I. e Nobili, L. (2017), Application of key performance indicators for maintenance management of clinics facilities, *International Journal of Strategic Property Management*, Vol. 21 No. 5, pp. 58-71, https://doi.org/10.3846/1648715X.2016.1245684.

Silva, S. C. (2011). *A gestão da actividade de manutenção em edifícios públicos - modelo e definição de estratégias para uma intervenção sustentável* (Tese de Doutoramento em Engenharia Civil). IST, Lisboa.

Taillandier, F., Sauce, G. e Bonetto, R. (2011). Method and tools for building maintenance plan arbitration. *Engineering, Construction and Architectural Management*, Vol. 21 Issue 4, pp. 343-362.

Vilhena, A. (2011). *Método de avaliação do estado de conservação de edifícios – análise e contributos para o seu aperfeiçoamento e alargamento do âmbito* (Tese de Doutoramento em Engenharia Civil). IST/LNEC, Lisboa.

Wood, B. (2009). *Building Maintenance*. Wiley-Blackwell. Retirado de: http://books.google.pt/books/about/Building_Maintenance.html?id=RRwgrj0TOs8C&redir_esc=y (18/07/2019).

List of Publications

Articles included in this thesis resulting from study and research

Journal Papers

1. Mendes da Silva, J.A.R., Falorca, J.
   A model plan for buildings maintenance with application in the performance analysis of a composite facade cover, *Construction and Building Materials*, Vol. 23, Issue: 10, pp. 3248-3257, October 2009,
   DOI: https://doi.org/10.1016/j.conbuildmat.2009.05.008.

2. Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R.,
   Research measurement of knowledge advances in building maintenance issues, *Structural Survey*, Vol. 32, Issue: 1, pp. 61-71, 2014,
   DOI: https://doi.org/10.1108/SS-08-2012-0023.

3. Falorca, J. F.,
   Main functions for building maintenance management: an outline application, *International Journal of Building Pathology and Adaptation*, 2019,
   DOI: https://doi.org/10.1108/IJBPA-08-2018-0067.

International Conference Papers

1. Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R.,
   Building maintenance and management - theoretical aspects and correlations, in: ICEUBI 2013, International Conference on Engineering, Engineering for Economic Development, 2013, November 27-29, University of Beira Interior, Covilhã, Portugal.

2. Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R.,
   Lean building maintenance - proposal for a conceptual approach, in: ICEUBI 2013, International Conference on Engineering, Engineering for Economic Development, 2013, November 27-29, University of Beira Interior, Covilhã, Portugal.

3. Falorca, J.,
   Models and systems of maintenance management - a review to introduce a comprehensive information system for buildings, in: ICEUBI 2017, International Conference on Engineering, a Vision for the Future, 2017, December 5-7, University of Beira Interior, Covilhã, Portugal.

4. Falorca, J.,

An integrated approach to the supporting resources function of an information system for building maintenance management, in: ICEUBI 2017, International Conference on Engineering, a Vision for the Future, 2017, December 5-7, University of Beira Interior, Covilhã, Portugal.

Chapter 1

Introduction

1.1. Framing the subject

The present study broadly discusses the theme of BMM. In the last decades, this subject has not been sufficiently explored in Portugal, both in the construction sector, where it was somewhat neglected by the absence of policies to promote it, as to some extent in the scientific environment in general, eventually because it was a subject which did not attract more attention due to the development model that was being followed. Adding to all this, the state and political power seemed to have, sometimes, adopted a foreign role, characterised almost by an absence of adequate legislative measures.

More recently, however, resulting from the economic crisis and by the consequent drastic reduction of new construction indices, the situation seems to be reversing, with the emergence of greater interest in this area, perhaps due to a reorientation of the construction sector towards urban rehabilitation and a greater awareness of the level of degradation of the existing building stock. Also, at the academic level, and particularly since the mid-2000s, a revival phase seems to have begun, mainly due to the sudden growth in the number of theses and dissertations. There have also been more related public events and an increase in economic activity in this niche of interest is visible, with a continuous rise and strengthening of companies in the sector.

For this reason, particularly at buildings level, it is important to differentiate the combined use of information management and engineering techniques, with the aim of monitoring their life cycle and to include specifications for the management and control of their maintenance, substitutions and the monitoring types and levels of utilisation. The BM, seen in a structured way, seems to be making significant progresses, although there is still a great deal of work to do in the construction sector. Therefore, although the economic climate and the current situation of construction make it possible to reinforce the idea that inspection and maintenance activity will have a significant reinforcement of its scale of implementation in a short/medium term (and despite still resorts to own methods), it sees herself already today, given the circumstances, facing increasingly demanding customers and situations, looking for efficient and faster services, without this entailing significant cost increases.

For example, notice the increasing urgency of many public, public-private and private entities opting for outsourced services to ensure the efficient functioning of their assets, thus eliminating in-house departments that are often unfit, as simultaneously are following a way

of deconcentrating their functions and an administrative modernisation. And instead, entities which have great structures of human resources and are trying to optimise their operation, opting for investing in the development of tools and methods more tailored to their internal reality.

However, this option requires great capacity for adaptation, diligence and innovation from both the companies and entities involved in the sector as well as from other players. Therefore, it is already very common the use of means which can facilitate these functions, as for instance, the wide range of options in Information and Communication Technologies (ICTs), specifically those more directed to support MM, in particular software or related software applications. In this case, a large number of options are currently available on the market with different approaches in terms of integration, functions and degrees of success. However, as regards specifically the scope of constructive elements as well as to many other particularities connected with the management acts itself, the environment and sustainability issues, energy, comfort, adaptation to a more extensive legislation, among many other aspects, it seems to be some scarcity of applications allowing a wide-ranging use, flexible and grounded in models or supports scientifically studied and tested.

In this sense, and essentially because the MM activity should not be carried out in an improvised and casual way, it seems essential the emergence and development of contributions aiming to improve ways of managing real estate assets through good planning of processes and activities, execution as planned, results evaluation, triggering of operationalisation and improvement actions according with the needs, integration of information and knowledge, among other aspects. It should be emphasised that nowadays, the efficient use of information is a critical success condition for any organisation.

Faced with the foregoing, it is believed that one of the following paths is through a greater study and development of guidelines for automatisation of procedures, scientifically based, which allow to open the way (or to provide the basis) for improvements, new forms and tools, seeking a higher-level performance of BM. This is surely a way which will provide this activity with a more sustainable strategic development.

1.2. Objectives and methodology

The main objective of this study was to outline an information system which is intended to become real in terms of a computer support, aiming to make it easier the functional performance of any organisation in the BMM activity sector, regardless of its size and kind of assets involved. Therefore, based on a coherent organisation, the intention is to establish a set of guiding principles or sustainable strategies which will allow, in the future, to enjoy a completely automated and simplifying procedures platform, through a base model of innovative design, more comprehensive and integrative of all information than many existing

systems or programs. For the bases of the information system, projected through an algorithm of procedures, it was given the name of Information System for Automatisation of Procedures in the BMM, herein cited generically as SIAPME.

Therefore, in essence, in order to achieve generally the above-mentioned main objective, other partial objectives were outlined, such as:

- To contribute to knowledge, dissemination and deepening of aspects related with maintenance and its good management;
- Raise the awareness of several stakeholders in the construction process and of managing entities for the need to plan and conduct a good management, particularly by making use of IT tools, as well as to the consequent favourable short-term impact and the undoubted long-term benefits related with the practical achievement of these aspects;
- To gather and structure technical and scientific information which will enable the management entities, particularly those of patrimonial issues, to improve knowledge on this subject and to assist in the implementation of adequate planning measures for the maintenance of their buildings;
- Arising from the performance of a bibliometric study, to offer a national and international perspective on the approximate growth model of the literature which should be considered of particular interest for BMM, as well as to make a small contribution to a possible improvement in the research agenda, also extracting an idea on the potential of the academic work here presented;
- To awaken the attention of several stakeholders of BM (especially of managers) to many of the current issues going beyond those intrinsic and conventional, such as the increasing use of ICTs, the aspects related with sustainability in the built environment, comfort, energy efficiency and the use of renewable energies and resources, etc., since these are short-term issues which must also have an integrated treatment;
- Through the detailed description of the outlined system, to present or propose to all interested parties (researchers, companies, organisations, etc.), a wide range of ideas on how BMM should be carried out and at the same time to offer a perspective on the vastness of aspects that should be taken into account so it performs effectively, up-to-date, in a comprehensive and integrated way.

Generally speaking, the methodology followed consisted of the following main steps:

- To study the diversity of existing bibliographical elements related with the different themes, in order to gather, assimilate and/or perceive the intrinsic knowledge;
- To gather and structure the most important resulting information in order to achieve the main objectives proposed;

- To gather and analyse, in a bibliographical catalogue, the titles of bibliography related with maintenance, which were considered of general interest for the activity of a building manager, making then a statistical and results treatment (bibliometric study);
- Following the previous step, to draw an overview (and as many as possible) about the evolution of knowledge;
- To investigate and understand some basic aspects of management used in the field of industrial maintenance since it was considered important to retain some knowledge in this field; also, to be able to apply it in real terms. In this respect, it should be pointed out that much of the theory and operability in the field of BM is intrinsically derived from this important and advanced sector of activity, and it was therefore considered that its knowledge should not be overlooked;
- To investigate and understand a set of models, procedures or methods developed, used or with interest for the BMM;
- To investigate and gain more detailed knowledge about Lean Thinking - since it has been a widely studied subject, with recent application in the construction sector. In addition, it was tried to verify in what way it could be used in the BM, and thus, to suggest an eventual theoretical application;
- To deepen knowledge and the understanding of aspects intrinsically related with ICTs - which serve or can support MM, as well as the composition and functioning of some existing programs;
- To synthesise the knowledge gathered and assimilated, performing in essence, a practical exercise of its application, with feasibility of use and future valorisation, based on an adequate set of sustainable strategies of MM. In other words, to outline an algorithm of procedures for a system called SIAPME, whose different stages are developed through the representation of a large number of organizational charts or hierarchical schemes, with several links between them, individually represented, for example, on several sheets of an MS Excel file.

In general, relevant literature was obtained by consulting repositories in libraries and mostly online, through Google, Google Scholar, ResearchGate, ScienceDirect, B-On, Emerald Insight, links to institutional sites, journals, etc., covering a wide variety of publication types, Web pages, and others. The information processing was carried out based on sorting each publication according to the themes and subtopics with interest for this work.

For the experimental adaptation test of a management function (the Resources Management) foreseen in the SIAPME model, a Visual Basic programming language was used, involving an autonomous pre-learning.

1.3. Main contributions

This section briefly describes the seven major scientific contributions, resulting from the research work presented in this thesis.

The first contribution briefly presents the concept of BM, some aspects about the phases which comprise life cycle of buildings, as well as types of management most feasible in the utilisation phase. This article also seeks to draw attention to the importance of deepening and discussing these topics and their interdependencies. It is basically an introductory literature review.

The second contribution of this thesis is about an approach to a Plan for Inspection and Maintenance in Current Buildings (abbreviation in Portuguese: PIMEC). This plan was designed for general use, and can be customised for each type of building solution, for each BE and/or eventually for each building material. The test and validation of this model was based on the inspection of a wide area of façades of a number of buildings covered with ETICS. The objective was to increase the knowledge about the organised methods of implementation of maintenance in the elements of construction which require special attention throughout its useful life. Through a practical test, it was yet possible to detail the maintenance model applied on ETICS and to provide an approximate knowledge of its in-service behaviour, as well as a notion about its possible durability - thus contributing to its dissemination and so that this type of façade finishing, became a more widely used material, mainly due to its excellent performance in terms of reducing energy losses through the envelope. Therefore, from this precursor work, a set of basic ideas were made available in order to achieve a more adequate organisation of certain aspects, related in particular, to inspection and maintenance of a current building.

The third contribution is a bibliometric study with which was tried to evaluate the general progress of knowledge in BM. On an approximate basis, it enabled the analysis of the growth of the whole body of literature production with this field related, and to assess which lines of research may require further study and development. This work involved a vast research study and a bibliographic systematisation of different aspects. Using several means of support, a detailed search of more than 2,000 publications titles was made. The research data were grouped into six pre-defined bibliographic indicators: ‘Books’, ‘Journal Articles’, ‘Proceeding Articles’ (both academic, technical or professional), ‘Theses and Dissertations’, ‘Standards’ and ‘Other Documents’. The results were gradually organised into a catalogue of bibliographic resources, for which MS Excel resources were used, which also assisted in the subsequent statistical counting and analysis process.

The fourth contribution is a summarised study of bibliographic review on several models, systems and methods for MM, referring some of those with origin and application in industry

in general, as well as the most important ones already developed and applied in buildings and buildings sets. This kind of study played an important role in the development of SIAPME. This contribution also embraces a brief comparative critical analysis, reporting some aspects of the convergence of SIAPME.

The fifth contribution presents a proposal for a conceptual approach to the application of Lean concept in GME. Resulting of a literature review in the field of Lean philosophy, this paper identifies several aspects which may give greater contribution for the procedural effectiveness in GME. It advises to introduce some Lean practices in the flows of a GME generic process, whose practice is suggested to be known as Lean Building Maintenance (LBM). The results of this rehearsal idealise an improvement on the acting performance through a greater agility in procedures, in order to reduce or eliminate the most frequent causes of waste. It is also intended that this knowledge arises in the conceptual basis of a development process of new tools, more efficient, as it can flow from SIAPME.

Then, the sixth contribution presents the general guidelines of an algorithm of procedures to be used in GME, generally referred to as SIAPME. Based on a broad literature review (updated here), this work consists of an exploratory practical exercise, involving several organisational charts with several interconnections. It offers an overview of a set of well-founded and integrated alternative strategies for asset management, independently whether it treats of one building or a set of buildings. Through the SIAPME procedures, it is given to General Manager a perspective on the wide range of his functions, covering almost all the fundamental aspects for an efficient and integrated maintenance, with ideal control of all the participants in the process. This is a conceptual idea which, when introducing technological and emerging issues, seems to bring great advantages for GME.

Resulting from the different stages of development of SIAPME, as described in the last paragraphs, the seventh contribution essentially refers to the presentation of general guidelines for a computerised adaptation, tested in one of the foreseen General Management functions of SIAPME: the ‘Support Resources’.

In fact, the importance of Supporting Resources (‘Resources Used’, the ‘Functional Organisation’ and ‘ICTs’) is fundamental to the complete success of the approach proposed by SIAPME. Thus, the Visual Basic programming language was used for study purposes only and a basic computer version was prepared. The results achieved show great potential, particularly regarding the identity and effectiveness of the envisaged procedures, as well as in the sustainable integration of all information required for an efficient management.

1.4. Organisation of the thesis

This thesis is simply organised into four chapters, since this was considered the most fitting line of presentation.

Chapter 1 frames the subject, presents the objectives and the methodology approach, a brief description of main contributions and the organisation of the thesis.

In chapter 2 a preliminary approach is completed, and it includes the first and the second contributions. That is, in section 2.1. an introductory literature review on various theoretical and correlational aspects in the field of BM and its management is presented. Subsequently, in section 2.2., a model of a PIMEC is addressed, as well as its test and validation, based on the inspection of a large area of façades of a number of buildings covered with ETICS.

Chapter 3 comprises some steps of development of a comprehensive application for the integrated management of BM, culminating in the presentation of SIAPME guidelines and a in a minor computerised adaptation focusing in one of its functions. This chapter covers from the third to the seventh contributions, and of these, the first three are fundamentally seen as bibliographical reviews. Namely, in section 3.1. a bibliometric study was carried out to evaluate the general progresses occurred in the knowledge of BM issues; section 3.2. comprises a brief bibliographical review of several models, systems and methods for MM; and section 3.3 presents a proposal for a conceptual approach to the application of the Lean concepts in GME. The basic principles and guidelines of SIAPME are then explained in section 3.4. At last, in section 3.5, it is described a computerised adaptation developed for a specific function of the model referred to above.

Chapter 4 presents the conclusions. Therefore, a framework is made, as well as the analysis of the main results achieved, an evaluation of the objectives, the difficulties and a few notes on eventual future developments.

Chapter 2

Model plan for inspection and maintenance of current buildings - a preliminary approach

2.1. Building maintenance and management – theoretical aspects and correlations

Contribution:

Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R.,

Building maintenance and management – theoretical aspects and correlations, in: ICEUBI 2013, International Conference on Engineering, Engineering for Economic Development, 2013, November 27-29, University of Beira Interior, Covilhã, Portugal.

Building maintenance and management – theoretical aspects and correlations

Jorge F. Falorca[1] / R. Calejo Rodrigues[2] / R. Mendes da Silva[3]
[1] Civil Engineer, MSc Construction Sciences, Covilhã, Portugal,
[2] Auxiliary Professor, Faculty of Engineering of University of Porto, Portugal
[3] Associate Professor, Faculty of Sciences and Technology of University of Coimbra, Portugal
jorge.falorca@netvisao.pt, calejo@fe.up.pt, raimundo@dec.uc.pt.

Abstract

This article briefly presents the concept on Building Maintenance, some aspects about the phases comprising the life cycle of buildings and the most workable management types at the use phase. The communication also seeks to draw attention to the importance of further deepen and discuss these topics and their interdependencies. It is basically a literature review.

Keywords: Building Maintenance, Maintenance Strategies, Building Management.

1. Preliminary Aspects

1.1. Framing the Theme

Since long ago, there are expressions of care and concern with the preservation and the performance of buildings, with particular focus on architectural heritage, mainly with the purpose of keeping it for future generations. Right now, buildings are taken as dynamic resources and not just as passive places where only one lives and works. The management and maintenance functions have been a different role, since they are considered as an essential responsibility to preserve, raising the maximum utility and value of buildings.

Therefore, the branch of Building Maintenance begins to have more and more a fundamental and decisive importance in their global management, contributing in general to increase the useful life of buildings, slowing aging and controlling costs.

1.2. Goals of the Article

With this paper we intended to expose some of the most important theoretical aspects addressed in an academic study [1], related with the necessary interdependence between the

basic principles of maintenance, the different stages of the life cycle of buildings and the Technical Management during the use phase.

Currently, it is desired that the Building Maintenance arises in a logic of a rational planning of periodical intervention strategies (single or combined) and of their administrative actions applied during the life of the building elements, thus desiring to be constantly producing useful information, improving the techniques and deepening the scientific knowledge.

It is therefore proposed to contribute to the knowledge and dissemination of all aspects of this subject and to raise awareness of all the players in the construction sector to the need of structured and arranged measures of maintenance become more effective from the early stages of a building.

2. Some Theoretical Aspects about Building Maintenance

2.1. The General Meaning of Maintenance

The word "maintenance" can be generically defined as: "*1. the act of maintaining...; 2. the state of being maintained...; 3. care or upkeep, as of machinery or property...*" [2]; or as: "*The act of keeping something in good condition by checking or repairing it regularly…*" [3]. However, according to other authors [4,5], the "*maintenance*" has its remote origin in the military vocabulary, with the sense of "*keep, in the combat units, the military personnel and the equipment at a constant level*". The concept can also be derived from the industrial processes with similar application to buildings, so that "maintenance is the combination of management, technical and economic actions applied to assets, for optimization of their life cycles"[6].

2.2. The Technical Concept Applied to Buildings

According the definition from the EN 13306:2010 [7], the maintenance service is the combination of all technical, administrative and managerial actions during the life cycle of an item - workplace (building), work equipment, or means of transport - intended to retain it in, or restore it to, a state in which it can perform the required function [8,9]. For the buildings in particular, an earlier standard from the British Standard Institution, BS 8210:1986 [10], defined Building Maintenance as work, other than daily and routine cleaning, necessary to maintain the performance of building fabric and its services [11], although the publication of BS 8210:2012 [12] replaces the original 1986 standard on Building Maintenance management, which has now been withdrawn. This standard applies to most types of building-related facilities, as for instance, those for health care, education, housing, manufacturing and distribution, commerce, retailing, utilities, communication and transportation.

For other researchers [13], it may also be assumed the meaning resulting from the standard ISO 6707/1 [14] in which maintenance is the combination of all technical and associated

administrative actions during the service life to retain a building or an assembled system in a state in which it can perform its required functions.

Thus, maintenance can be part of the overall procedures of the Technical Management of buildings, which activity best fits to Civil Engineering field, covering all kinds of actions in order to ensure the performance of the constructive solutions, either by correcting deviations or by the evaluation of the operating conditions. It should be stressed that occasionally, this word may arise for many stakeholders in the construction sector with a generalist sense and may often be confused with the rehabilitation of buildings or even be frequently used with a dual connotation: conservation and renewal.

In any case, more important than the definition of maintenance, is that the right work gets done. According to some authors [11], the "*right*" Building Maintenance can have the feasible components as stated in Table 1.

Table 1 - Possible components of "Right" Building Maintenance (according to [11])

"Right" Building Maintenance	
R	Reusable components, standardised systems, methods and materials
I	Intelligent customer focused, not necessarily automated, close fit
G	Green, low embodied energy, low impact, light and lean, right place
H	High responsive, finely tuned, individual users have control
T	Technological advances fully investigated, used for recording

2.3. Maintenance Strategies

With the forecasting and realization of proper maintenance strategies, it's possible to determine the moments during the life cycle of the elements in which is necessary to conduct the repairs or the replacement actions. Only thus we can optimize costs and resources and minimize the expenditure required for such interventions. In the Building Maintenance, the reactive and proactive maintenance strategies are usually considered – as shown in Figure 1.

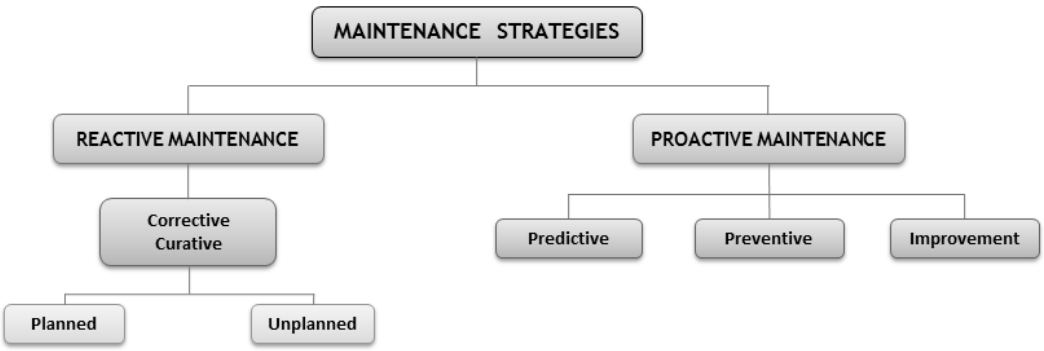

Figure 1 – Strategies usually considered in the Building Maintenance activity

2.3.1. Reactive Maintenance

Reactive maintenance consists in acting after a malfunction event that requires repair or rehabilitation. I.e., it allows the evolution of the degradation mechanism of an element to then make an intervention.

The reactive maintenance can also be referred as curative maintenance or corrective maintenance. It also ensures the repair of the defects and can be subdivided into:

- Small sized – it recognizes and assists the work to restore the original condition, with the exception of improvements or reconstruction works;
- Large sized – it requires substantial resources and it is linked typically to the field of improvements, reconstruction or rehabilitation;
- Emergency - it has a reactive and immediate approach.

It may seem that in a short term, this kind of maintenance is a less costly way of acting, but on the contrary, it can increase the costs. These can only be minimized by the implementation of procedures involving rapid responses for the resolution of the anomalies, within pre-established economic parameters.

The reactive maintenance may also appear as an advantageous solution; however, during the operation of a building, there are some drawbacks, such as [15]:

- Difficulties in intervening before various urgent situations - due to lack of planning;
- Rapid degradation of some building elements by the absence of users complaints (or because it treats of cases of costly repairs);
- The need to appeal to external companies to perform the interventions, leading to higher costs - mostly because there are no means capable for timely responses (or are insufficient).

2.3.2. Proactive Maintenance

This type of strategy can also be commonly referred to as preventive maintenance or systematic maintenance.

It integrates management concepts, such as the planned actions according to predefined criteria and aims to reduce the likelihood degradation of the elements to higher levels than the pre-established requirements. Within the proactive maintenance it is possible to identify three different types of maintenance: Preventive Maintenance, Predictive Maintenance and Improvement Maintenance.

Table 2 summarizes some technical features related with this subject matter.

Table 2 - Technical features related with the different types of Proactive Maintenance [15,16]

		Technical Features
Proactive Maintenance	Preventive Maintenance	It establishes and executes a set of maintenance actions based on planning and fixed periodicities, allowing a decrease of extraordinary work and consequently less interference with the normal utilisation of the building. The use of Preventive Maintenance aims to act in time before the occurrence of the anomalies or defects, pre-establishing the life of components and materials, as well as replacements or repairs, within that same life.
	Predictive Maintenance	The Predictive Maintenance (or condition-based maintenance) is based on the performance of maintenance activities, depending on the analysis and observation of the degradation state of the different elements. The inspections are firstly planned, instead of the activities to be executed. It aims to act in a timely manner earlier to the occurrence of anomalies or defects. I.e., it is supported by a fixed schedule of periodic inspections during which are evaluated and recorded the anomalies that have taken place and are identified the symptoms of any pre-rupture. This situation requires a rapid reaction of the maintenance services. Its implementation, through its own methodology of inspections and diagnostic methods, expresses as advantages the ability to detect when, how, and where the action is needed and enables a reduction in the number of unforeseen anomalies.
	Improvement Maintenance	It consists in the implementation of activities aiming the improving of the initial characteristics, by changing some elements of the building, avoiding its insufficient functionality. It makes sense in cases as: 1. Replacement of parts or components whose operation and/or durability have proved to be inadequate; 2. Replacement of components with early degradation; 3. Changes in some solutions that made school in limited periods of time and have provided however to be inadequate over time. Therefore, it is considered as a complement to Predictive Maintenance.

3. The Life Cycle Process of Buildings

3.1. Stages

The life cycle of a building includes several stages: (i) Promotion and Planning, (ii) Design and Engineering (Project); (iii) Manufacturing of Materials and Components; (iv) Construction; (v) Use and Maintenance; (vi) Demolition [15,17].

3.1.1. Promotion and Planning Phase

This is the first stage of the process. In this period, it is economically justified the construction, considering its functional benefits, which can be quantified by the rents and by the value of the building. The owner must define the useful life required for the building and its finishing's.

The useful life is the period since its opening until it reaches a specified degradation or a poor level of functioning, whereas there is a current maintenance.

3.1.2. Design and Engineering Phase

It is at this stage that should be thoroughly evaluated the following aspects [15]:

- The choice of appropriate technological solutions to implement;

- The durability and functionality of the materials;
- The overall costs of the technical solutions to be adopted;
- The safety and accessibility conditions in the execution of operations during the life of the building.

Here it must be noted that designers have an important role in the choices made. There is always the temptation to opt for technical solutions with a lower initial cost, often resulting in higher overall costs later, usually related with costly burdens of maintenance.

3.1.3. Phase of Manufacturing of Materials and Components

It is very important the need to increase scientific studies during manufacturing of new materials in the sense of be available a wider range of technical solutions to follow in the design and implementation period (mainly for those involved in the construction process - especially designers) - thereby supporting the execution of appropriate operations during the Use and Maintenance phase.

Moreover, it is likewise important that manufacturers and suppliers consolidate the knowledge about the performance of their products through their constant analysis and improvement, basing for such on the necessary information collecting about its service behaviour.

The need to undertake a good quality control during the manufacturing and supplying of materials is also intended to ensure the outlined life span. To achieve this, it is required to impose a strict compliance with the mandatory specifications and standards, as is the case of the Regulation (EU) No 305/2011 for the marketing of construction products [18], which indicates the essential requirements to be met by the materials.

3.1.4. Construction Phase

The good performance of buildings in service is dependent on the way were carried out the construction works. In general, these are responsible for most cases of anomalies during the use phase. A good quality control is the best process to ensure the planned useful life and it should be performed by the contractor and verified by the building work supervision. The main activities related with the durability are [17]: (i) the analysis of the properties of structural materials; (ii) the control in situ; (iii) the construction methods. Besides, during the construction phase, it's essential that contractors and subcontractors comply with the legal principles, respecting the project settings and technical specifications. Likewise, the entity responsible for overseeing the project should increase their effectiveness to ensure good levels of quality and full compliance with the legal obligations.

3.1.5. Use and Maintenance Phase

A building in use is a system with its own characteristics and can be problematic to understand it. Such characteristics are interconnected to ensure the performance of the whole. The performance is only achieved through mechanisms whose complexities are, mostly, restrictive to be analysed and interpreted. Such difficulties arise particularly from the following aspects [19]:

- Wide range of users' activities;
- Proper and inappropriate utilization forms;
- Large number of functional responses played by the buildings;
- Wide variety of elements, components and materials which constitute the buildings;
- It results of a phasing and not of a single action.

In general, the analysis of a building behaviour in service is made globally, i.e., the building is viewed as a whole and it is compared with a standard. Thus, performances or behaviours are not analysed; instead are made comparisons adjusting the same building as a pattern of a new one or with an ideal solution on the same date. The intrinsic aging and degradation are some aspects which make it possible to do this kind of confrontation.

However, it is usual to present the building performance through the time evolution of the quality level displayed, which is understood as being the weighted response that the different systems give to the functional requirements imposed on them.

The degradation is the inability of some building systems to respond to the initially planned functionality. Thus, the maintenance services are responsible for the resolution of these disabilities, sustaining the initial level of quality.

In Figure 2 is attempted to characterize the Use and Maintenance phase, the building behaviour and the degradation factors.

4. Building Management

4.1. Considerations

A building can be considered as a resource and as a material asset. Thus, a key objective of its utilization, involves the optimization of these aspects.

The 'resource' is composed by the building or by the physical building with all its technical features. Obtaining a functional response as long as possible, within the parameters set at the time of his conception and at the lowest cost, implies the maximization of its performance during the use phase.

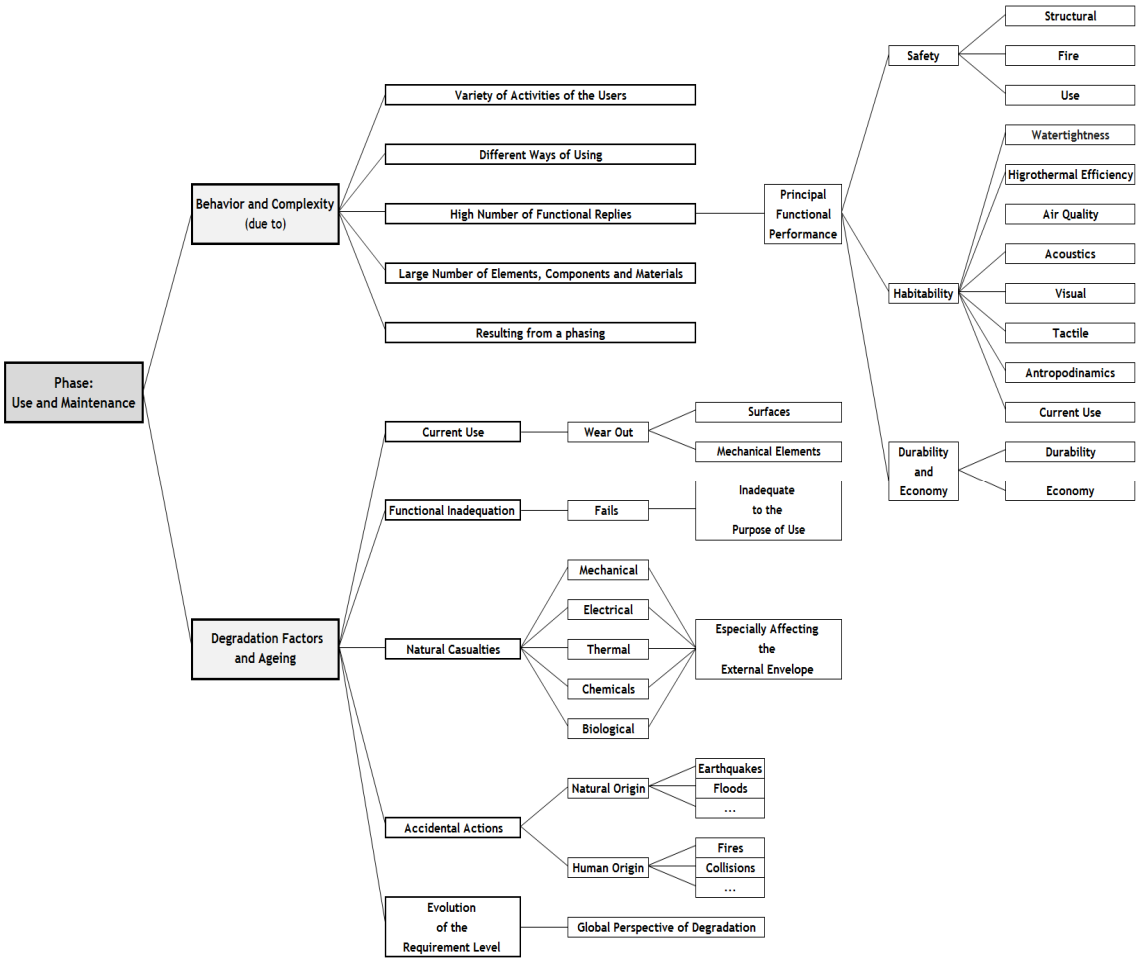

Figure 2 – Characterization of the Use and Maintenance phase of a building (organized from [1,19])

This is only possible if there is a posture of the user or by the manager, typical of the management function, being characterized by [13]:

- Optimize the use;
- Promoting maintenance actions;
- Analyse the behaviour and proceed accordingly;
- Protect.

On the other hand, a building is a 'material asset', because it has well defined and particular characteristics, among which stand out the longevity and the patrimonial value while real asset [20]. With respect to the longevity, questions of durability are associated, resulting from the guarantee of performance and of the economic importance which takes the useful age of the building.

4.2. Technical Management

The Technical Management of buildings is the one most related with the Civil Engineering, once it covers all kinds of actions in order to guarantee the performance of the constructive

solutions and its parts or components, correcting the functional deviations and assessing the operating conditions. Fundamentally, it represents the overall procedures implicit to the Building Maintenance.

It is especially in the technical aspect that a building presents the greater difficulties in its management. Recently, there are concepts such as "durability", "versatility" and "reliability" which have a considerable weight for those who have to perform the Building Management. According to these concepts, the repair or rehabilitation techniques are constantly changing. For instance, a repair is almost not only to restore a particular function, but can go further by checking if will not cause any decrease of durability, an inappropriate aesthetic impact or even to provoke any irreversible option [19].

4.3. Economic Management

Whereas it is increasingly common the influence of the deferred costs along the life cycle of buildings in the economic balance of the investment made with the same, it is mostly at the level of these deferred costs which concentrates the economic activity. This includes all financial and accounting processes related to buildings and stemming from charges of their operation.

The deferred costs can be divided into [13]:

- Maintenance costs - resulting of the maintenance actions;
- Operating costs - resulting from the activities developed into the building;
- Financial costs - generally with influence in the development process, from the initial planning phase until the use phase;
- Fiscal costs – associated to the registration or transaction of the property.

The responsibilities of the Economic Management involve:

- To stimulate the economic means to channel the funds needed to cover such costs;
- To optimize the application of the funds according with the needs of the moment;
- To oversee and control the investments realized.

4.4. Functional or Social Management

This activity is related with a guarantee of supporting the development of an appropriate use of the building, with particular emphasis on the duties and obligations of the wearers. The Functional Management is subdivided into the following processes [13]:

- Regulation of the activity;
- Economy in the use;
- Promotion of the Technical Management.

Under the scope of these processes, it is to this type of management that, in general, rules or criteria have to be defined and behaviours framed, to thereby meet the ordinary needs of the users.

4.5. Managing Bodies

The general duties of a Building Manager are represented in Figure 3, which in generally, are in line with what has been referred above.

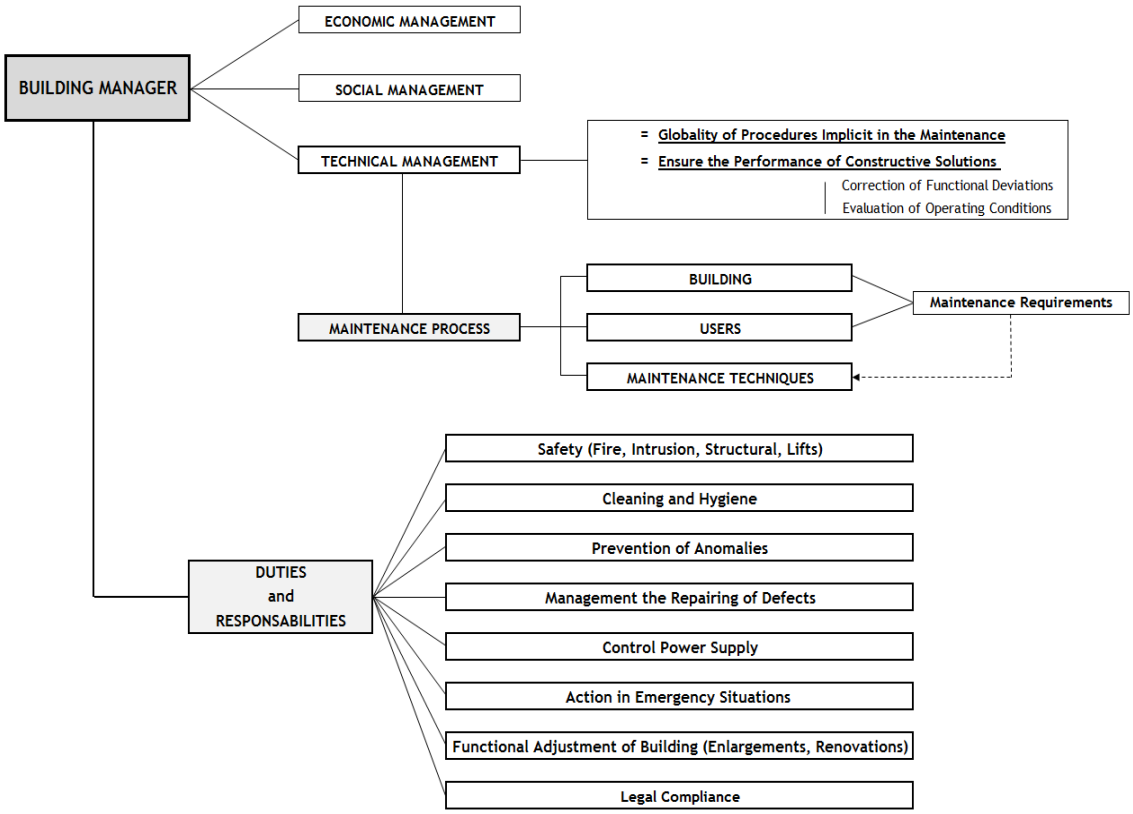

Figure 3 – The Building Manager: management tasks, duties and responsibilities (organized from [1,13])

At the Technical Management level and for the overall procedures implicit in the Building Maintenance, there are three key elements to consider in this process: the building itself, the users and maintenance techniques. Maintenance requirements stem from the interaction of the building with its users; and the means by which maintenance is performed, stem from its techniques. In the preparation of inspection and maintenance plans for buildings and their components, the cover of all important aspects for an efficient management of resources and costs is also necessary, while safeguarding the objectives of the Building Management companies:

- Prolonging the durability of the elements;
- To comply with safety requirements;
- To comply with the requirements of functionality;

- To comply with local conditions;
- To comply with the available budget.

5. Concluding Remarks

The implementation of maintenance methodologies arises from the context of the Building Management and it is an integral part of all phases comprising the life cycle of buildings. So, it is imperious to identify the importance of the different levels of that process for an appropriate management system of buildings, in which there is a constant intervention of the designers and a solid information collection. This will be also used as a knowledge base in the realization of future projects. It is also important to stress the importance of the management actions around the issue of Building Maintenance and durability. Thus, in the particular case of Building Management, must proceed according with three perspectives. The first one relates to the implementation of Technical Management, which covers all kind of actions in order to ensure the performance of constructive solutions, to correct functional deviations and to evaluate operating conditions. Essentially, it corresponds to the most maintenance procedures. In a second perspective, it's essential to perform the Economic Management, so that in this way, during the lifetime of the building, it may be possible to control the influence of deferred costs in the economic balance of the investment made with the same. Finally, it is also essential to ensure the Functional or Social Management of the constructions, namely promoting the proper use of the buildings through the definition of rules and behaviours which meet the common needs of its users. Throughout this perspective, it is necessary to be knowledgeable about the theory of the Building Maintenance strategies, which were briefly presented. Figure 4 seeks to systematize some correlations between the issues addressed.

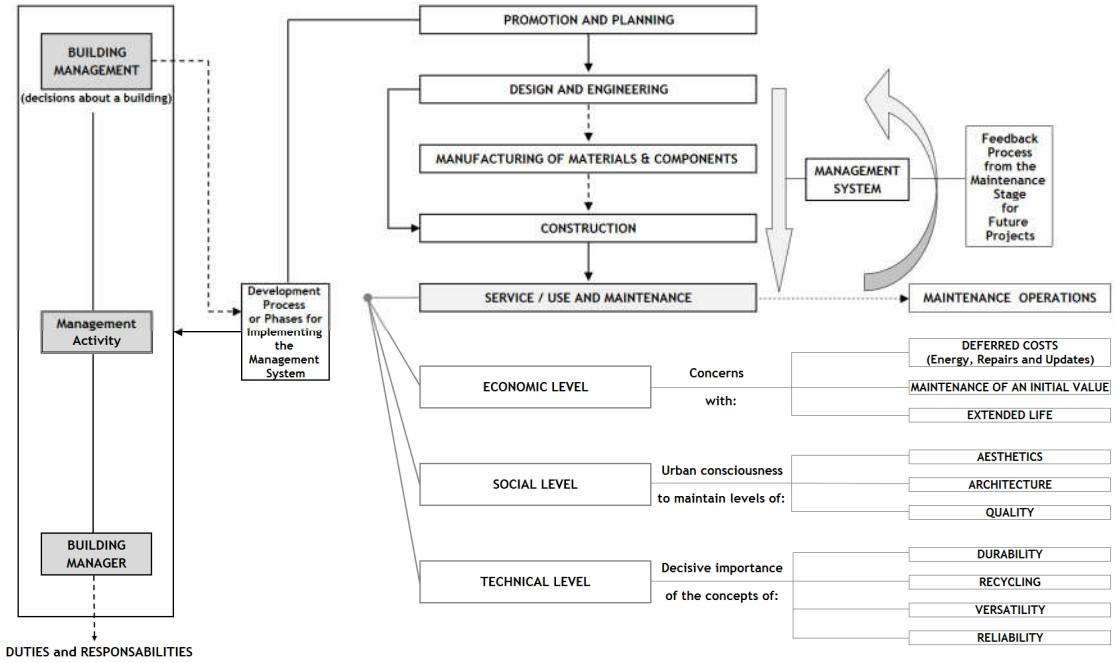

Figure 4 – Stages for implementing the management system (organized from [1,15,17,19,21])

References

[1] J. Falorca. Modelo para Plano de Inspecção e Manutenção em Edifícios Correntes, Tese de Mestrado. Faculdade de Ciências e Tecnologia de Universidade de Coimbra, 2004.
[2] Dictionary.com. http://dictionary.reference.com/browse/maintenance?s=t (18/07/2013)
[3] A.S. Hornby. Oxford Advanced Learner's Dictionary of Current English, Sixth Edition. p. 774, Oxford University Press, 2002.
[4] Almeida, Anabela A. A Gestão da Manutenção, Livro de Comunicações do Congresso Ibero-Americano de Manutenção - "Manutenção – Pilar Fundamental da Competitividade Empresarial", Lisboa, 1998.
[5] J.M. Torres Farinha. Uma abordagem terológica da manutenção dos equipamentos hospitalares. Porto, FEUP, 1994.
[6] J.S. Cabral. Organização e Gestão da Manutenção – Dos Conceitos à Prática. LIDEL, 1998.
[7] CEN, EN 13306:2010. Maintenance Terminology. (Referred in [8,9])
[8] European Agency for Safety and Health at Work. Maintenance and OSH — A statistical picture. 2010. https://osha.europa.eu/en/publications/factsheets/90. (23/07/2013)
[9] COCIR. Good Maintenance Services Practice Guide, Optimising the Equipment Life Cycle. http://www.cocir.org/site/fileadmin/Publications_2013/13004.COC.Good_Maintenance_WEB.pdf (23/07/2013)
[10] BSI, BS 8210:1986. Guide to building maintenance management. (Referred in [11])
[11] B. Wood. Building Maintenance. p.4/5, Wiley-Blackwell, 2009. http://books.google.pt/books/about/Building_Maintenance.html?id=RRwgrj0TOs8C&redir_esc=y (23/07/2013)
[12] BSI, BS 8210:2012, Guide to building maintenance management. http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030231187 (23/07/2013)
[13] R. Rodrigues. Gestão de Edifícios – Modelo de Simulação Técnico-económica. Dissertação de Doutoramento, Faculdade de Engenharia da Universidade do Porto, 2003.
[14] ISO, ISO 6707/1. Building and civil engineering vocabulary – Part 1: General Terms. 1989. (Referred in [13])
[15] I. Colen. Estratégias de Manutenção – Elementos da Envolvente de Edifícios. Dissertação de Mestrado, Instituto Superior Técnico, Lisboa, 2002.
[16] Brito, J.; Branco, F.: "Manutenção Pró-Activa de Obras de Arte". Ingenium, 2.ª Série, n.º 57, (2001), pp. 42-47.
[17] Branco, F. Conceber Edifícios Duráveis. Palestras do 1º PATORREB, "1.º Encontro Nacional sobre Patologia e Reabilitação de Edifícios", Faculdade de Engenharia da Universidade do Porto, 2003.
[18] European Union. Regulation (EU) No 305/2011 of the European Parliament and of the Council laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC. March 2011.
[19] Abrantes, V., Calejo, R. Planeamento das acções de manutenção em parques habitacionais. Comunicações do 2º ENCORE, Encontro sobre Conservação e Reabilitação de Edifícios, Vol.II. LNEC, Lisboa, Junho-Julho, 1994.
[20] E. Natividade. Avaliação do Espaço Urbano Edificado com Recurso a Tecnologias da Informação. Tese de Mestrado, Faculdade de Ciências e Tecnologia de Universidade de Coimbra, 2002.
[21] Flores Colen, I. Planos de Manutenção Pró-activa em Edifícios Recentes. Comunicações do 3º ENCORE, Encontro sobre Conservação e Reabilitação de Edifícios, LNEC, Lisboa, Maio, 2003.

2.2. A model plan for buildings maintenance with application in the performance analysis of a composite facade cover

Contribution:

Mendes da Silva, J.A.R., Falorca, J.,

A model plan for buildings maintenance with application in the performance analysis of a composite facade cover, *Construction and Building Materials*, Vol. 23, Issue: 10, pp. 3248-3257, October 2009,

DOI: https://doi.org/10.1016/j.conbuildmat.2009.05.008.

A model plan for buildings maintenance with application in the performance analysis of a composite facade

J.A.R. Mendes Silva *, Jorge Falorca
*Department of Civil Engineering, Faculty of Science and Technology, University of Coimbra, Rua Luís Reis Santos, 3030-788 Coimbra, Portugal.

Abstract

The efficiency of maintenance of ordinary buildings is quite relevant in regard to their durability and functionality. It requires an accurate method for planning the different actions involved. This paper deals with some results of one of these models, being developed at the University of Coimbra and oriented toward the maintenance of school buildings, where an External Thermal Insulation Composite System (ETICS) was adopted. The model plan, called PIMEC, was developed in an organized system using the common methods of building maintenance. It can be employed as an algorithm to create informatics applications, allowing the active procurement of component performance data throughout the life of a building. PIMEC differs from past studies in that all the information resulting from the simulated inspection and maintenance procedures in the elements can be organized with a configuration of straightforward consultation files. In order to test and validate the proposed model, it was analysed large buildings facades covered with ETICS. This paper explains the content of some important stages and the applicability of ETICS by presenting the results of its performance behaviour analysis. Through this specific case study it is intended to show not only the potential of PIMEC but also the extraordinary advantage of slight but accurate maintenance actions over the anticipated lifetime of ETICS.

Keywords: Building maintenance, Facades, External finishing, ETICS.

1. Introduction

The building maintenance policies, with their relatively minimal expression in Portugal, have been applied with success in other countries but have involved significant investments in the construction sector. With the increasing costs of new construction, the maintenance of

existent buildings has become even more important, allowing the qualification of the built park, the economy, the well-being of the users and the valorisation of spaces.

Additionally, the buildings' quality challenges pass with respect to the environment rules. The need to save energy and natural resources has become obligatory and essential. New energy codes [1] impose a minimum standard of the energy conservation in new buildings, driving energetic improvement to the fabric of construction, and consequently heating costs are decreasing as an important contribution to environmental protection. In this way the requirements for heat insulation on building envelopes have significantly increased in recent years. The external wall insulation systems apparently have a life expectancy that can match if the buildings to which they are applied are correctly maintained. As a result, high requirements are placed on ETICS and the functional lifetime of this material must still be studied.

This paper reports some of the results of an MSc thesis that has proposed a model for planning inspection and maintenance in ordinary buildings, which Portuguese acronym is PIMEC [2]. It was conceived for generic use, and can be customized for each kind of construction solution, for each construction member, and eventually for each building material. In order to test and validate the proposed model, it was decided to analyse building facades covered with ETICS (thin, reinforced synthetic mortar over an external insulation layer). The University of Coimbra has over the past 12 years adopted this insulation technique for a large number of buildings erected at the new campus, resulting in an impressive experimental sample for this research work. The goal is to extend the knowledge on organized methods of implementing maintenance in building elements that require special attention throughout its lifetime, in order to increase the general durability and avoid the incidence of superfluous costs during the usage phase. With practical testing, it was possible to detail the maintenance model applied to ETICS, supplying an approximate knowledge of its real service behaviour and feasible durability and making of this facade's finishing a more utilized material, mostly due to its contribution to the reduction of energy loss on the envelopes of buildings.

The results have important implications for both managers and researchers as they provide insights into the mechanism of how a building maintenance method permits to obtain important theoretical results concerning the durability of its elements.

2. Background

2.1. Building maintenance sector

The construction industry has, for 18 years, attempted to incorporate sustainable development principles for the purpose of improving the well-being of current and future generations. In the European Union, the maintenance sector had two periods that marked the development of the maintenance concept. The period after the Second World War saw the

introduction of economic and durability principles that influenced the decisions of demolition or conservation of buildings, while an enormous built park was erected, constituted by housing buildings and facilities of a public, commercial or industrial nature. Then, on a stable economic phase with stagnation in population growth, the construction industry embraced the maintenance and rehabilitation to improve the habitability demands of an important number of existing buildings with dubious technical quality. More recently there has been an enormous technical evolution through the enhancement of comfort standards, as defined by the users, and by a significant expansion occurring in the tertiary sector, accompanied by the implementation of sophisticated equipment and integrated services to satisfy the needs of the corresponding companies. According to the recent data of Euroconstruct reporting to 2006 [3], the maintenance and rehabilitation activity of the European Union corresponds to approximately 50% of the residential sector and 43% of the non-residential sector, representing 37% of the total for the construction sector.

In Portugal, the recent history of the built patrimony is not coincident with the course verified in the rest of Europe. This is because Portugal didn't directly suffer the devastating effects of the Second World War. Its evolution was largely a result of the tentative industrialization process initiated in the 1960s, as well as the implementation of construction politics for social dwellings after the Revolution of 1974. Over the past several years, construction development has basically been sustained through significant investments in equipment and infrastructures with public interest, in the expansion of urban areas promoted by the city halls in order to use the financial resources, and in the materialization of the Expo 98 and Euro Football Championship 2004 Projects. This realization of new construction was not accompanied by the recovery of the oldest buildings, as a consequence of the freeze on dwelling taxes supported by the Estate. Nowadays is frequently to see the promotion of new construction in the periphery of the cities, much to the detriment of the culture of building preservation, principally in the old urban nucleus, with the consequent depopulation. The Portuguese housing stock is relatively recent, with approximately 57% of buildings being new than 30 years of age [4]. In 2006 were estimated 3.4 million building units [5], of which only a small percentage was for non-residential use. However, its conservation state is already preoccupying. The investments in new construction largely overcome the work of repair and maintenance. For instance, in Portugal, in 2006 new construction in the non-residential sector corresponds to 91.5% [3].

In fact, the maintenance of Portuguese buildings is mainly based on an empirical approach. There are three main reasons for this: insufficient budgeting for intensive and systematic maintenance; insufficient public knowledge of maintenance benefits; and a lack of technical models and support tools to help planning actions, in this domain, matching the Portuguese reality. Most of these facilities are ordinary buildings, despite their diversity of architectural solutions and construction options.

2.2. Maintenance management advances

To solve the problems related to maintenance management and adopt the proper procedures, several norms were created, most significantly the BS 8210 [6] The glossary of associated terms is defined in the BS 3811 [7] and the corresponding vocabulary can be found in the ISO 6707-1 [8].

The NF X 60-010 [9] standard defines the five levels of maintenance associated with the growing degree of intervention. The smallest stage corresponds to the preventive maintenance operations, followed by the corrective maintenance, major repairs and reconstruction. The NBR 14.037 [10] establishes a compulsory nature to the constructors to elaborate manuals for use and maintenance and the NBR 5674 [11] foresees the preservation or the re-establishment of appropriate environmental conditions to the anticipated use of buildings. Other guides for maintenance actions [12] have established the repair procedures for the occurrence of different defects, and a connected law [13] forces the delivery to the residents of a building book. To make its application easier, some informatics programs have been developed with instructions for the maintenance of constructive elements and facilities [14] or to support technical tasks relative to building maintenance management, specifically those organized in proprietors' condominiums [15].

Accurate guidelines [16] create the connection between maintenance execution and the estimated lifetime value while expressing several performance steps for the elements of a building. Some manuals [17] specify that each building element can have one or more associated control operations in agreement with a degradation scale and an intervention scale. The improvement of maintenance operations in the elements over the lifetime of the building can be also found among several technique files [18], including the most favourable periods for each maintenance intervention. The requirements and procedures for the effective building operation, maintenance, decommissioning and demolition were developed by certain organizations [19] together with details of the building's construction, history and maintenance, instructions for its operation and maintenance, and its guarantees and warranties. Additionally, different maintenance works are considered with emphasis on the importance of building performance, whether they are viewed as an investment, asset or facility [20]. A small guideline [21] shows how maintenance plans can be established, dealing with the strategic and procedural matters that must be considered. However, the right execution of the maintenance and repair work presumes safe access to all of a building's facilities while requiring the best practice guidance, specifically in the design of a new building [22].

Other tools [23] have been designed to help government building facility managers adopt the best practices for environmentally preferable operation and maintenance. Many municipal

governments throughout North America have imposed codes for housing maintenance [24], most of them based on international standards [25].

Lastly, reference is made to the International Council Research and Innovation in Building and Construction (CIB), whose activity has made a great contribution to the development of knowledge in all fields of building and construction. In 2008, the Working Commission W70 (Facilities Management and Maintenance) has accomplished the International Conference in Facilities Management, whose themes scope ranges several researches outcomes [26], including the maintenance management issue.

2.3. National research

It is clear that the theme of building maintenance has drawn considerable interest from the scientific community, and this has had repercussions in Portugal. Consequently, as outlined in the context of this subject, some research studies have been developed. The analysis and exploration of a database on a housing park is known [27], and several proposals for methodologies concerning building maintenance and exploration have been characterized [28]. Subsequent studies [29] have accomplished the identification of certain pathological anomalies in the building envelopes of a housing group, thereby developing a statistical approach to the emergence of anomalies in a short-to-medium period and researching the periodicity and depth of ‘‘major maintenance interventions” and beneficiation actions. The concepts for the practical application of organized maintenance and management [30] have been gathered and presented, essentially addressing the issue of industrial maintenance, despite their being applicable as general concepts from a building’s perspective. The need to predict the building’s service behaviour during its useful phase was the motivation to develop a simulation model supported in the Monte Carlo method and adjusted to the necessary interventions in buildings [31].

Others approaches to buildings maintenance, based on the degradation curves of their facade coating materials, are known in Portugal [32] but do not include ETICS. Furthermore, it would be difficult to adapt other approaches to Portuguese climatic conditions and their influence on facades.

3. PIMEC approach

3.1. Subject

A maintenance plan is a group of specifications accomplished in the context of the maintenance process, being designed to program preservation actions. The development of these methodologies must begin in the early phase of construction (i.e., the design phase), and a dynamic actualization must be carried out during the exploitation phase. They constitute precious tools of support for the entities with responsibility in the building’s management, whose main objective is to monitor the performance of the constructive

solutions, elements or components, with a constant correction of the operation conditions and then issue warnings as necessary.

The establishment of a plan of inspection and maintenance in current buildings, being forward assigned for PIMEC, involves diverse basic phases through an in-depth analysis. Each of these phases will present a duly ordered configuration of procedures (using, for example, letters and numbers). A set of orientation lines for the establishment of a permanently adjusted dossier (plan files) will result from this arrangement.

3.2. Main configuration

The base proposal configuration for PIMEC (see Fig. 1), has two initial phases involving a series of procedures. The attributed assignments and references are merely examples. It is pretend that the plan files be organized in agreement with that configuration, including all information resulting from the design process and other information collected later, mainly in the usage phase.

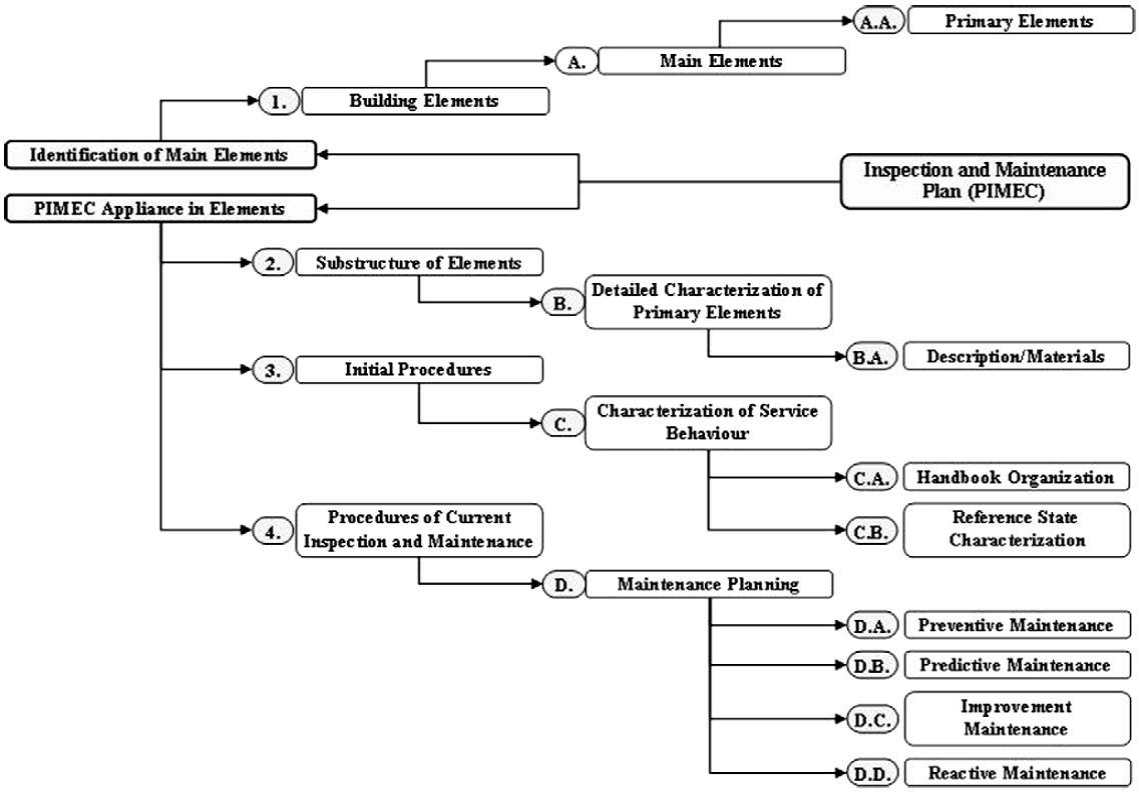

Fig. 1. Base scheme proposal for a PIMEC [2].

3.3. Identification of elements

The modulation of building performance requires the acceptance of the interaction among the elements. However, to the general analysis of durability it becomes useful to identify them separately as independent nucleus of degradation. Consistent with the defined criteria analysis of modulation of building performance [31], this study, in its context, attempts to

indicate some of the usually elements of buildings that require maintenance care throughout their lifetime and considered with emphasis on the practical application of an inspection and maintenance plan (Table 1). This subdivision can still include other elements not mentioned in this paper, depending on the characteristics of a particular building.

Table 1 - General building elements with importance to application of PIMEC.

1. Building elements			
A.	Main elements	A.A.	Primary elements
1	Base elements	A.A.1.1	Foundations
		A.A.1.2	Support walls and outlying contention
		A.A.1.3	Structure
2	Compartment elements	A.A.2.1	Walls
		A.A.2.2	Roof
3	Finishing elements	A.A.3.1	Facade covers
		A.A.3.2	Doors and windows

3.4. Application of PIMEC

Subsequent to the general characterization of building (stage A.A.), planning maintenance with PIMEC includes a large number of procedures and actions, organized as follows: detailing of elements and materials (B.), knowing their performance under service conditions (C.) (see Fig. 2) and establishing guidelines for technical actions and their specific schedule (D.).

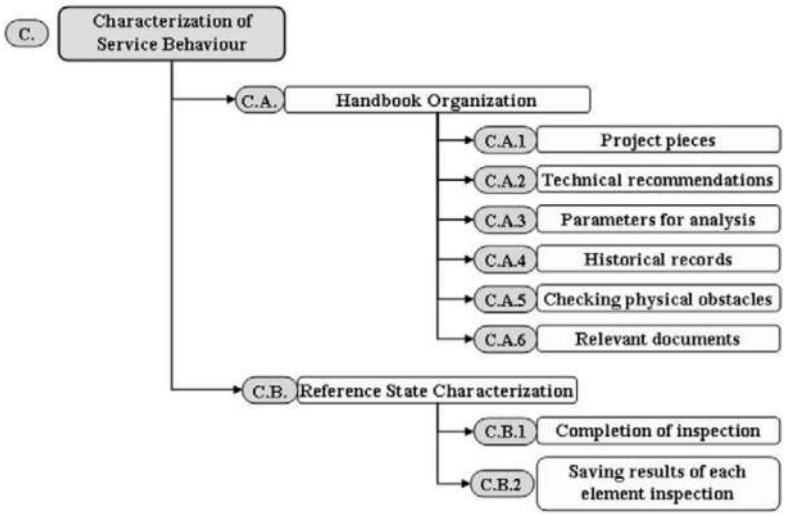

Fig. 2. PIMEC: initial procedures organizing scheme [2].

The Handbook Organization (C.A.) includes some important aspects to support an efficient administration of resources and costs, in agreement with the objectives of the managing entity. Later, this paper will focus on stage (C.B.), Reference State Characterization, in which the actual performance of building elements is observed and stated.

The final stage consists of analysing the Procedures of Current Inspection and Maintenance (D.), specifically the subject of maintenance planning. This requires an objective analysis for

each group of technical actions whose accomplishment is demanded during the lifetime of the building element, thus characterizing the relevant considerations that give credibility to several referee strategies.

For example, Preventive Maintenance (D.A.) (see Fig. 3) studies the characterization of the involved parameters and registers the degradation of building elements. A schedule of preventive maintenance is then developed, arbitrating and studying several strategies for intervention and using various maintenance operations, all of which have previously been defined and budgeted.

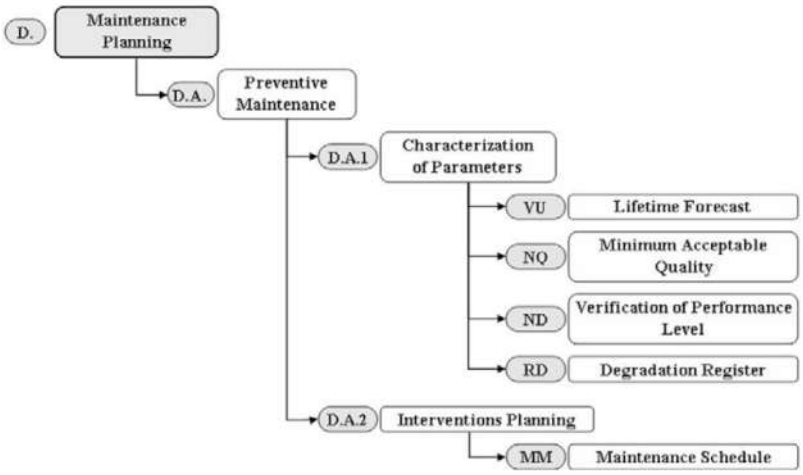

Fig. 3. Procedural scheme for preventive maintenance [2].

A PIMEC has pretended to be a dynamic process, involving constant adjustments since the existence of new information or when considered essential to adapt it, aiming to take appropriate decisions in agreement with the available budget. The knowledge acquired throughout the maintenance process can be used in future actions, but for such to occur a database is needed. Therefore, all the ordinary activities of PIMEC should be registered. Preferably, the evaluation of existing information should be made annually in order to lessen the doubts connected with any consideration.

This method allows the constant correction of the implemented PIMEC, based on the knowledge and experience that are acquired and transmitted through the record of activities.

4. Case study

4.1. Scope of application

The test of PIMEC was carried out on four selected recent buildings of common typology (concrete structure, concrete walls and masonry), despite their modern and outstanding design. These buildings (with different acronyms shown in Fig. 4) are mainly of the Engineering and Research departments of the University of Coimbra, and have been designed by international teams of architects.

Fig. 4. Selected buildings and their facades.

The facades of all these buildings (more than 37,000 m2) are covered with ETICS, using synthetic insulation boards 30–60 mm thick and thin, synthetic mortar, painted with a light colour (white or light grey).

ETICS, a high-performance thermal insulation component, has recently been introduced into building technology. It is provided as a good aesthetic solution, and its high thermal resistivity supplies energy efficient for building envelopes. One of the most important issues in terms of its application to a building is to minimize failure in service and to guarantee a service life in the range of several decades under typical stress conditions, particularly the thermal and hygrometric effects. However, there isn't sufficient knowledge regarding the long-term properties and durability of ETICS to support its study in the current subject matter. Anyway, an international literature research concerning ETICS, already shows some studies of different sort, developed on this material. A quick review of the advantages of ETICS is available [33] and other revision [34] contains a detailed description of the main system components, quoting the advantages and details for its correct application whilse evaluate the impact on the energy consumption of buildings. Previous relevant studies [35] discuss different methods of insulating existing buildings, present the major limitations and problems with its application in adverse climates and summarizes several recommendations for thermal insulations of buildings. Other study [38] based on the proceeding set by ISO 15686 [36] and referring to ETAG 004 [37], was aimed to build up a design method of durability of ETICS with rendering and intended to assess the definition phase and the preparation phase in order to achieve an exposure testing program meant to evaluate the degradation intensity and the service life. In a similar context of present work, it's possible to point out a research [39] with several results of repeated inspections of multi-storey and larger buildings with ETICS over longer periods of time and state other investigations [40] with reference to the

performance of ETICS. Still concerning the process deterioration, were made some predictions of moisture and temperature strains acting on an ETICS with mineral wool insulations under natural climatic conditions and normal usage, using computational simulations [41].

According to the defined configuration for PIMEC, ETICS is a primary element of the façade covers (A.A.3.1), particularly of the building's envelope (see Table 1). In order to main such elements, it can be classified as a finishing element (A.3). Falling back upon the analysis of the responsibility notebooks of different constructions, and based on certain important published documentation in Portugal regarding this façade cover technique [42,43], simple drawings, pictures and detailed characterization of the different layers can be filed.

4.2. Reference state characterization

Once the Handbook Organization (C.A.) is complete, we will focus on stage (C.), particularly on the Reference State Characterization (C.B.) (see Fig. 2). This step is necessary in order to establish a maintenance plan, not only because it gives technical information about performance and degradation (including its prevention and rehabilitation) but also because it helps to adjust the theoretical degradation curves.

4.2.1. Methodology

All the facades of the analysed buildings have thus far been inspected twice in order to obtain the essential data needed to approach the reference state characterization for ETICS, as defined by PIMEC. Table 2 summarizes the main guidelines of this procedure.

Table 2 - ETICS – reference state characterization [2].

1.A.A.3.1 Facade covers – ETICS
3. Initial procedures
C. Characterization of Service Behaviour
C.B. Reference State Characterization
C.B.1 Inspections accomplishment
First stage: preparation of field work, with the selection of aspects and defects with importance to analysis, creating tables to save inspections results
Second stage: considering the high surface of the building's envelope, a small calendar observation is made
Third stage: employ a simple inspection technique in the field work, which, in this case, is a visual inspection to confirm the existence of previously identified defects:
– System unstuck
– System perforation
– Irregular surface
– Surface cracking
– Visual defect of board interface
– Insulation boards swell up
– Colour change
– Parasitic vegetation
– Defects over corner reinforcement
Note: Considering the mentioned tasks, it can come necessary the accomplishment of more complex inspections
C.B.2 Saving results of each element inspection
For management archives organization, an inspection report model should be filled out and always filed in this sifter

The first inspection occurred at 2004 and the second one at 2006; in both cases, the inspection action was based on visual identification of defects, according to a pre-defined list based not only on scientific publications, but also on previous Portuguese experience [42,43]. Despite the accuracy and detail of the data collected on defects, only the existence or the

non-existence of each defect, for each ‘‘module” of facade, is considered in establishing the reference state characterization. The relevance of additional information obviously concerns another layer of this process, i.e., the technical approach to maintenance actions and their scheduling.

4.2.2. Types of defects

Three groups of defects have been observed during both inspections: (i) surface defects, (ii) cracks and (iii) local deterioration. Fig. 5 illustrate some of these defects.

Surface defects – including parasitic vegetation, areas soiled by rainwater, and irregular surfaces – that affect a wide area of the facades are particularly inconvenient in what concerns visual comfort and aesthetics, but there is no evidence of their consequences on the physical performance of the wall (thermal insulation, waterproof, mechanical strength and cohesion).

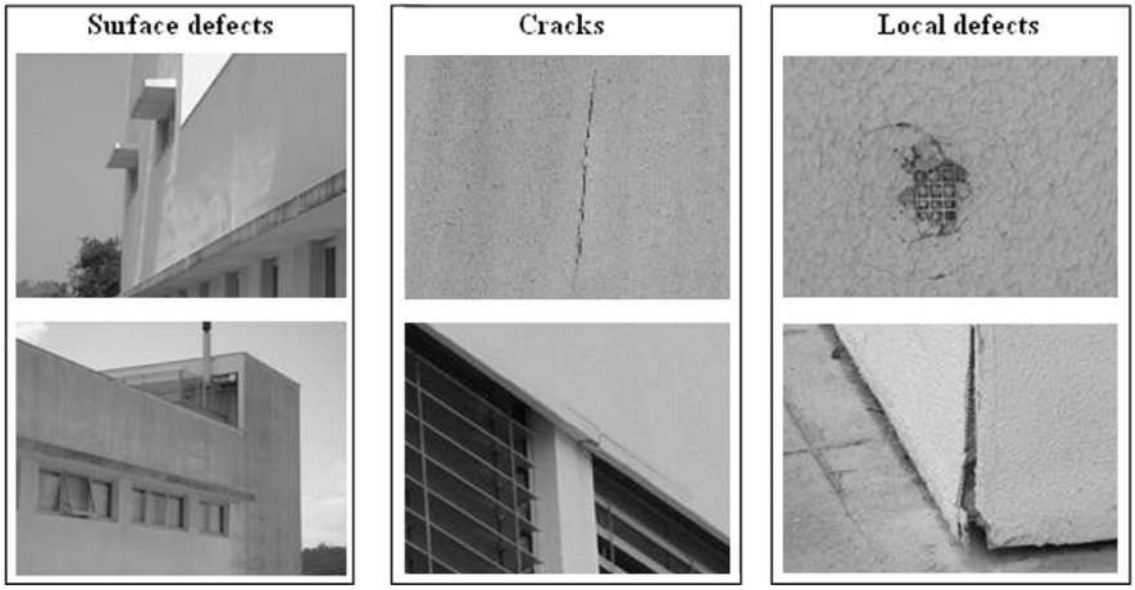

Fig. 5. Examples of different groups of defects.

Parasitic vegetation case has already reached about 17,685 m2 of surfaces area, most of all in the two exposed buildings about environmental terms (DEEC and DEI), each one with a huge volume and extensive surfaces. These aspects, linked to the local thermal and hygrometric conditions, can justify the main reasons to the appearance of this defect. In fact, it was verified that the buildings facades with South orientation (opposite to Mondego river valley) are the most affected. It seems that parasitic vegetation growth can be directly connected with the environmental aggressiveness of large facades, in particular due to prolonged surface wetness (rain or night-time surface condensation) – which may be judged to be visually unacceptable – also according to some authors [39]. The expansion movements and retraction forced by local and seasonal thermal extent can be the reason to become visible irregular surfaces in about 13,855 m2.

Cracks occur in 79% of total number of facades, but they affect only small areas. The more relevant are the cracks between insulation boards (mainly due to a deficient execution of the system) and local cracks over metal reinforcements of the ETICS system. Unlike surface defects, cracks promote the progressive deterioration of ETICS and of the facade's physical performance.

Local defects result mainly from mechanical actions – unpredictable use or vandalism – that perforate the thin external mortar layer and the reinforcement mesh, leading to the progressive degradation of ETICS. These phenomena occur at confined areas but can be responsible for a general degradation. It is important to remember that the most relevant function of the reinforced external mortar layer of ETICS is to protect the insulation boards against rainwater, prevent the migration of humidity into the wall, and prevent the deterioration of insulation material and the increase of thermal conductivity. Local perforation often affects this basic function.

4.2.3. Inspection results

Fig. 6 presents the general results of the first inspection (2004) and the evolution of each defect (2006) for all the facades of the selected buildings (taking into account the medium between occurrences in the total areas and in the number of facades). Three types of defects affect more than 50% of facades: colour degradation, irregular surfaces and cracks. Loss of adhesion between insulation boards and the masonry wall is the defect less often observed. The number of facades newly affected by each defect over the last two years is between 1% (for visual defects at the surfaces of insulation boards) and 23% (for parasitic vegetation) with a mean value of 11%. Also important is the colour change and dirtiness (due to rainwater and atmospheric contamination) that reach nearly all the facades (35,785 m2) after this period of time [44].

The harmful effect of these anomalies is not proportional to the percentage of affected facades, since their evolution and predictable contribution to reduced wall physical performance are quite variable. Based on other works [45], a scale of anomalies has been created, with four levels of degradation in which each kind of defect is considered.

Allowing for the same initial consideration used in the previous diagram, Fig. 7 represents the proportion between all nine different main defects, grouped according to this conventional graphical scale of anomalies. This methodology is an additional and expedite form to support the effective maintenance planning of ETICS, since it allows evaluating constantly each event weigh by a growing ranking of influence (level 1 to level 4), mostly due to own defect capacity to harm radically the general performance. Besides, it is possible to get a qualitative evaluation of the element condition. The distribution of anomalies for each degradation level was decided considering the value of each defect at all and the recognized importance of its probable interference in the element real state.

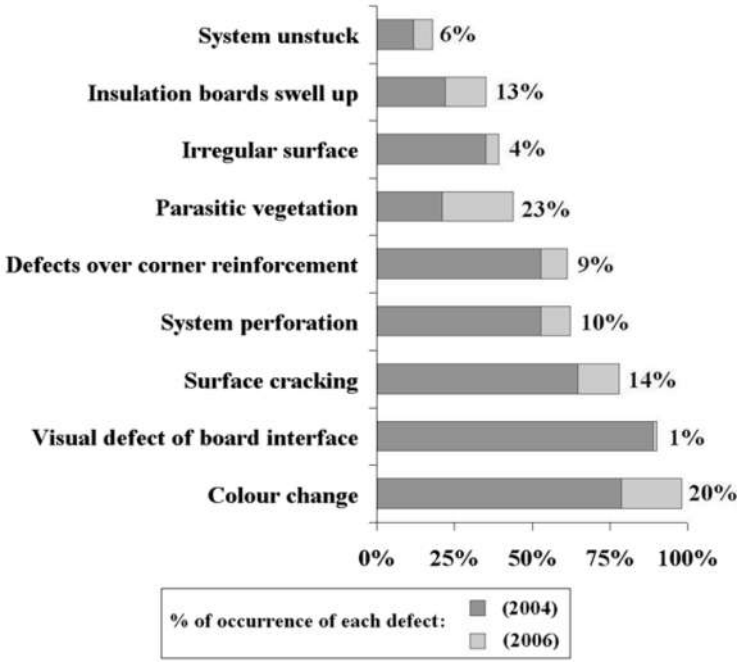

Fig. 6. General evolution of affected facades by each main defect: case studies [44].

Despite the different evolution for each defect, the general layout is the same for this period of time. It clearly shows that degradation level 4 is quite insignificant, while level 3 comprises 46% of the detected anomalies.

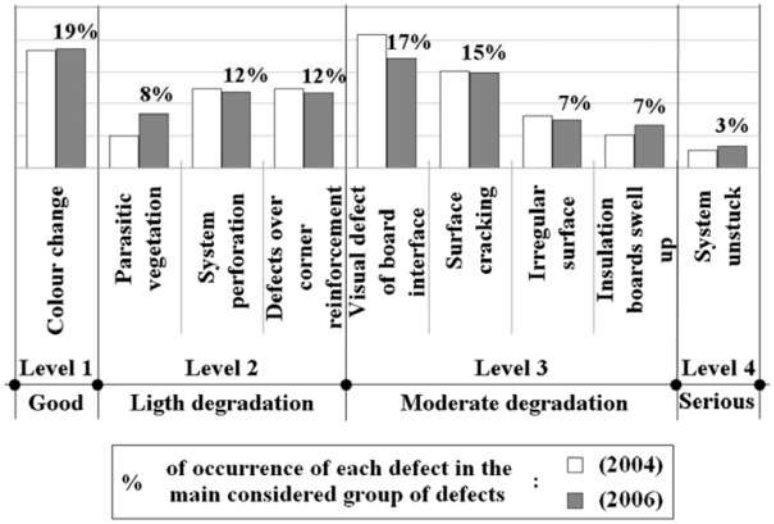

Fig. 7. Evolution of relative importance of each defect distributed by degradation levels [44].

4.3. Planning maintenance

4.3.1. Characterization of parameters

At the first stage, PIMEC suggests a theoretical approach to maintenance planning based on conventional lifetime curves and minimum quality levels for buildings. Then, PIMEC encourages the use of a case-by-case approach based on inspection and analysis, as shown for ETICS in the previous sections and Table 3.

Table 3 - ETICS – characterization of parameters in the planning of preventive maintenance [2].

1.A.A.3.1. Facade covers – ETICS
4. Procedures of Current Inspection and Maintenance
D. Planning of Maintenance
D.A. Preventive Maintenance
D.A.1. Characterization of Parameters

Proceeded to a life time analysis based in an *Evaluation (Av)* by an *Estimate (Es)* using as *Alternative (Al)* some available *Information (Id)*. The representative values of lifetime obtained were:

VU

–For an inexistent maintenance level: 28 years
–For a normal maintenance level, including visual inspections, cleanings and periodic repairing: 35 years
–For a good maintenance with maintenance operations with reduced periodicity: 42 years

The minimum acceptable quality should be established, for instance, in the technical specifications of building project as an initial *Register (Ri)*.

In this case, it's necessary to create a *Criteria definition (Dc)*: it is supposed that the minimum quality level should be approximately 20% to an incidence of anomalies that correspond to any circumstance no longer accepted in the performance-demand point of view.

The perspective value of the lifetime, for this performance and without maintenance, is 24 years.

To the defined minimum quality level, theoretically is supposed been reached serious degradation states, such as:

NQ

- General system perforation
- General surface cracking or deep cracking
- Adherence loss of insulation boards and/or in the board interface with eventual detachment
- Deep deterioration over corner reinforcement
- Deep colour changes

From where implicate or result above all:

- Accentuated infiltrations and waterproof losses
- Considerable alteration of the term-hygrometric demands initially extolled
- Significant visual degradation that reaches the minimum requirements of aesthetics
- Other, in the verification of the performance level

In Portugal it is still hard to predict the lifetime of ETICS, since this system is being used only for 16 years – in a few buildings – and case studies are rare. Moreover, its multilayer constitution represents an additional difficulty when it is necessary to know the global durability of the facade.

Usually, it is possible to present the durability of a building element by different qualitative models, described through typical degradation curves, almost connected to different exterior mechanisms with strongly incidence: close to a straight linear line when associated to wind; a convex line when associated to pollutant agents; a S line when associated to water mechanical effects; and a concave line when linked to biological attacks – algae, mushrooms, etc. Thus, the approach to the real performance is increasingly larger if it's based on an appropriate methodology of analysis of the degradation mechanisms, supported by the understanding of the most important anomalies, of the main local external deterioration agents as well in an accurate evaluation of effects and in the quality level of the construction process. Thus, in a theoretical point of view, it is promising to delineate a typical degradation curve of an element, presuming a qualitative sense of the main combined effects.

At this particularly case, if we accept the conventional homogeneity of the system, some assessment tools are available [16,32,36,43,46] and, in conjunction with the reference state behaviour, it is possible to suggest a theoretical degradation curve of ETICS and a total value of the performance. ISO 15686-1 [36] suggests minimum design lives for components associated to the design life of buildings, considering the maintenance requirements and the opportunity to specify more reduced values of durability. In a first approach, at this particularly case of study (with a specific type of buildings and components), is admitted a 40-year-old value. Other bibliography [43], especially concerning to ETICS, refers that its durability can be dear as being superior to 30 years, in case of normal use conditions and

high-quality design and construction. However, to predict the total lifetime approximation, a simple simulation of the factorial method was accomplished, just as it proposes the A.I.J. [16], admitting a medium value of those behind referred (Y_S = 35 years). So, in normal conditions of buildings service and following a careful choice of factors with influence in the lifetime of ETICS (to an inexistent level of maintenance and taking into account the general reference state characterization), it was seemed acceptable a 28-year-old value corresponding to total failure (performance 0%).

Fig. 8 represents the degradation curve of the system without any maintenance action – also based on similar models [32], simulated by a second-order polynomial function, with an initially degradation tax slowly increased, becoming lightly accelerated as it tends for the lifetime ends. As a result, it is possible to estimate a lifetime of 24 years for a minimum performance of 20%.

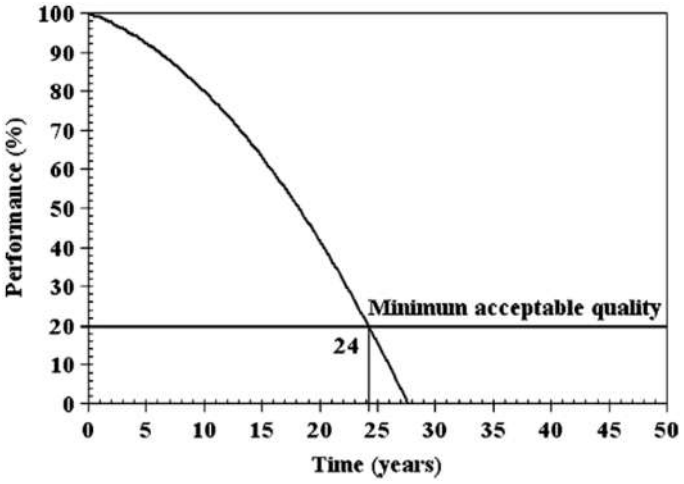

Fig. 8. Degradation curve proposed for ETICS without maintenance [2] based on similar models [32].

4.3.2. Intervention planning

Several maintenance strategies and the consequent temporary schedules of intervention have been simulated. A schedule with the seven economically strategies in the case of preventive maintenance is represented in Table 4. The decision criterion to select the most favourable strategy was supported by Life Cycle Cost (LCC) method.

A predictive maintenance strategy is characterized by a median value of the material behaviour in real conditions, represented by a T_m curve. On the other hand, a preventive maintenance strategy is characterized by a theoretical pessimistic behaviour corresponding to a T_k curve. In probabilistic terms it can be associated to the superior characteristic values of the degradation tax. This means the use of predictive strategies allows to verify that the normal real behaviour can be slightly superior to that admitted for a preventive strategy [32]. Likewise were also admitted the following hypotheses: (i) the accomplishment of a 5 year-old close inspection action, admitting that the material presents an inferior degradation of about

20% relative to the Tm curve; (ii) the accomplishment of periodic inspection actions one year before each repair intervention and another three years before the end of the resulting life cycle.

Table 4 - ETICS – preventive maintenance schedule: seven economical strategies [2].

1.A.A.3.1 Facade Covers – ETICS

4. Procedures of Current Inspection and Maintenance

D. Planning of Maintenance

D.A. Preventive Maintenance

D.A.2 Intervention Planning

Maintenance Schedule

MM

Y	0	1	2	3	4	5	6	7	8	9	10	11	12
S													
2.1													
2.2										⊡			
2.3								⊡					
3.1	🛠												
5.1													
5.2													
5.3										⊡			

Y	13	14	15	16	17	18	19	20	21	22	23	24	25
S													
2.1		⊡											
2.2						⊡							
2.3		⊡							⊡				
3.1		◈											
5.1		⊡											
5.2		⊡											
5.3						◈							

Y	26	27	28	29	30	31	32	33	34	35	36	37	38
S													
2.1			⊡						↺				
2.2			⊡									⊡	
2.3			⊡							⊡			
3.1			◈										
5.1			◈										
5.2			✶										
5.3													

Y	39	40	41	42	43	44	45	46	47	48	49	50	51
S													
2.1													
2.2			↺										
2.3				⊡				↺					
3.1				◈							↺		
5.1		↺											
5.2							↺						
5.3			↺										

Legend:

Y	Year of intervention	◈	Quick repairing
S	Strategy	✶	High repairing
🛠	Cover application	↺	Replacement
⊡	Cleaning		

Fig. 9 shows the degradation curve for one of the simulated scenarios of predictive maintenance for ETICS, according to PIMEC and similar models [32]. In this specific case a global cleaning action is considered at the 16th year (half the predicted minimum lifetime), followed by a high repair at the 32nd year, resulting in a 50% increase of predictable lifetime (thus reaching 48 years).

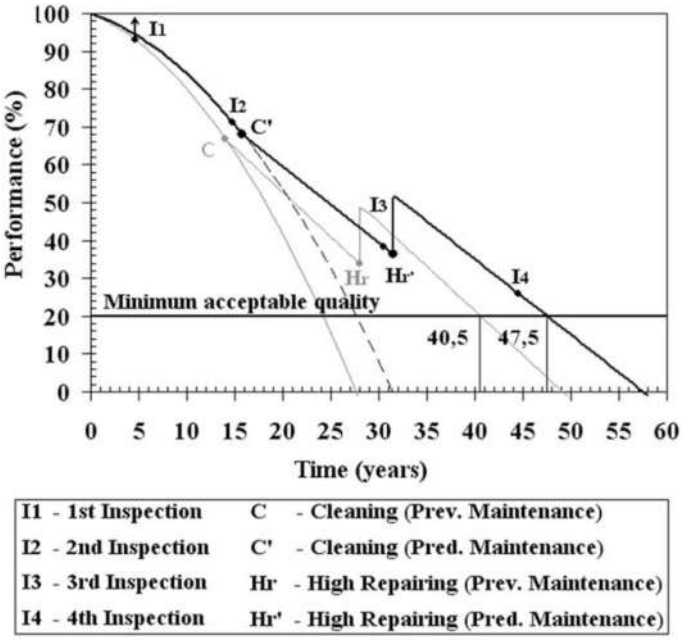

Fig. 9. Example of degradation curve proposed for ETICS under a specific maintenance scenario [2] based on similar models [32].

5. Conclusions

This research work has produced a configuration for an inspection and maintenance model referred to as PIMEC, attempting to make its realistic analysis on ETICS (External Thermal Insulation Composite System).

The establishment of a PIMEC process leads to the identification and characterization of all building elements, straight to the gathering of significant information. Furthermore, there is an increased need to constantly understand the behaviour of all elements, together with the storage of resulting information in each analysis. With PIMEC it is often possible to increase the relative knowledge about the parameters involved in the simulation of forecasted maintenance procedures, being able to present simplified approaches by understanding the interaction among the building's elements. It also promises the unification of information through a model of rapid consultation files. The presented proposal configuration for a PIMEC intends to be a debatable model, in the sense that one finds a better, more effective solution.

The survey of more than 37,000 m2 with ETICS has been presented, and its results have been analysed under the scope of that proposed method. Thus, it was possible to certify some theoretical advantages of its use, such as flexibility, the permanence of a good aesthetic level of the external walls, and the satisfaction of criteria such as thermal comfort and minimization of thermal bridges. Moreover, it was also possible to conclude that the environmental conditions and the execution mode of ETICS have significant influence on the variations of its behaviour patterns. Given the practical rehearsal of the maintenance

planning in agreement with the different actions perspectives, we studied the theoretical modulations applied on ETICS, supplying a perspective of what could prove to be its long-term behaviour. Probably the most important aspect to take from this study is the indication that any type of maintenance accomplishment allows to achieve quite good theoretical results in terms of durability. In the case of ETICS, its durability can be duplicated through the application of maintenance efforts similar to those proposed.

References

[1] Characteristics regulation of thermal behaviour of buildings. Decree–Law no. 80/2006. Portugal: Laws and Decrees; April 2004 [in Portuguese].
[2] Falorca J. Model plan of inspection and maintenance in ordinary buildings. M.Sc Thesis, Department of Civil Engineering, Faculty of Sciences and Technology, University of Coimbra, Portugal; 2004 [in Portuguese].
[3] National Association of Contractors of Public Works. Notebooks of construction. Report of the 63rd conference of the Euroconstruct in plague, Portugal; 1st semester of 2007 [in Portuguese].
[4] Census 2001. Statistics Portugal; 2001.
[5] Statistics of the construction and housing 2006. Statistics Portugal; 2006 [in Portuguese].
[6] BSI – BS 8210 – Building maintenance management. BSI, British Standards; 1986.
[7] BSI – BS 3811 – Glossary of maintenance management terms in terotechnology. BSI, British Standards; 1984.
[8] ISO 6707-1 – Building and civil engineering vocabulary – Part 1: General terms. Switzerland: International Organization for Standardization; 1989.
[9] Norme NF X 60-010. Maintenance – concepts et définitions des activités de maintenance. France: Association Française de Normalisation; 1994.
[10] NBR 14.037 – Operation manual of use and maintenance of constructions – content and recommendations for elaboration and presentation. Brazilian Association of Technical Norms, Brazil, 1998 [in Portuguese].
[11] NBR 5674 – Maintenance of constructions – procedure. Brazil: Brazilian Association of Technical Norms; 1999 [in Portuguese].
[12] NTE. Technological norms of edifications. Spain; 1972 [in Spanish].
[13] LOE. Ordination law of edification. Spain; 1999 [in Spanish].
[14] Building manual. Institute of construction of Castilla and Leon, v. 4.0. Spain; 2007 [in Spanish].
[15] CLAU2000 – Assistant de manteniment – libre de l'edifici test manteniment reports, Collegi D'aparelladors i Arquitects Tècnics de Barcelona; 2000.
[16] The English edition of principal guide for service life planning of buildings. A.I.J. – Architectural Institute of Japan; 1993.
[17] Arbizzani E. Technologies for maintenance of real estate patrimonies and nets. ICIE - Cooperative Institute for Innovation; 1991 [in Italian].
[18] Perret J. Guide de la maintenance dès bâtiments. Paris: Monitor Référence Technique; 1995.
[19] Operation and maintenance manuals for buildings – a guide to procurement and preparation. CIRIA; 1999.
[20] Chanter B, Swallow P. Building maintenance management. Blackwell Science; 2000.
[21] RCIS Books. Building maintenance: strategy, planning & performance. UK: The Royal Institution of Chartered Surveyors; 2000.
[22] Iddon J, Carpenter J. Safe access for maintenance and repair. CIRIA; 2004.
[23] Green building maintenance manual. Pennsylvania Department of General Services. <http://www.dgs.state.pa.us/dgs/lib/dgs/green_bldg/greenbuilding book.pdf>.
[24] NYC housing maintenance code. Department of Housing Preservation and Development – Office of Rent and Housing Maintenance. <http://www.tenant.net/Other_Laws/HMC/hmctoc.html>.
[25] International property maintenance code. International Code Council; 2006.
[26] Book of proceedings of the CIB W070 conference in facilities management, healthy and creative facilities. Edinburgh: Heriot Watt University; 2008.

[27] Calejo R. Building maintenance: analysis and exploration of a database on a housing park. M.Sc. Thesis, F.E.U.P., Porto; 1989 [in Portuguese].
[28] Gomes J. Methodology for the maintenance and exploration of buildings. M.Sc. Thesis, I.S.T., Lisbon; 1992 [in Portuguese].
[29] Taborda R. Maintenance management of a housing park – experimental model for estimation. M.Sc. Thesis, F.E.U.P., Porto; 1995 [in Portuguese].
[30] Cabral J. Maintenance organization and management – from the concepts to the practice. Lisboa: Lidel; 2004 [in Portuguese].
[31] Calejo R. Buildings management – model of technical and economic simulation. Ph.D. thesis, F.E.U.P., Porto; 2001 [in Portuguese].
[32] Flores I, Maintenance strategies - current building's envelope. M.Sc. Thesis. I.S.T., Lisbon; 2002 [in Portuguese].
[33] Rouni G. Efficient energy thermal insulation facade systems for optimal savings and flexibility in architectural design. In: International conference passive and low energy cooling for the built environment, Greece; 2005. p. 487–92.
[34] Panagiotis D. Thermal insulation façade systems: optimal energy savings, better investment practices. <http://www.srcosmos.gr/srcosmos/showpub.aspx?aa=10619>.
[35] Spitzner M. Thermal insulation of buildings: materials, properties and systems. The annual insulation conference, Dubai; 2003. <http://www.fiwmuenchen. de/PDF/Sonderdr_Thermal_Insulation_2003.pdf>.
[36] ISO 15686-1 – Buildings – service life planning – Part 1: General principles. Switzerland: International Organization for Standardization; 2000.
[37] ETAG 004. Guideline for European technical approval of external thermal insulation composite systems with rendering. Brussels: EOTA; March 2000.
[38] Daniotti B, Paolini R. Durability design of external thermal insulation composite systems with rendering. In: 10th DBMC international conference on durability of building materials and components, Lyon; 2005. p. 749–59.
[39] Künzel H et al. Long-term performance of external thermal insulation systems (ETICS). Acta Sci Polon Archit 2006;5(1):11–24.
[40] Nieminen J. Case studies on external wall insulations systems faced with thin render. Papers published in ICBEST '97, Centre for Window and Cladding Technology (CWCT), Bath; 1997. p. 441–6.
[41] Holm A, Kunzel H. Combined effect of temperature and humidity on the deterioration process of insulation materials in ETICS. In: Proceedings of the 5th symposium on building physics in the Nordic Countries, Gothenburg; 1999. p. 667–84.
[42] Mendes da Silva J et al. Natural aging and pathology of external thermal insulation composite system in facade walls. In: Proceedings of the 2nd international symposium about pathology. Durability and rehabilitation of buildings. Lisbon: LNEC; 2003 [in Portuguese].
[43] Lucas J. ITE 24 – Classification and general description of coverings for masonry walls or concrete. Lisbon: LNEC; 1990 [in Portuguese].
[44] Mendes da Silva J, Falorca J. Advances in ETICS behaviour analysis and consequences for planning maintenance. In: Proceedings of the CIB world building congress, construction for development. South Africa: Cape Town International Convention Center; 2007. p. 612–22.
[45] Gaspar P. Methodology for service life prediction of external cementitious renders. M.Sc. Thesis, I.S.T., Lisbon; 2002 [in Portuguese].
[46] Sjotrom C et al. Implementation of the European construction products directive via the ISO 15686 Standards. In: Proceedings of the 9th international conference on durability of building materials and components, Australia: Brisbane Convention Centre; 2002 [paper 010].

Chapter 3

Development of a comprehensive outline application for the integrated building maintenance management

3.1. Research measurement of knowledge advances in building maintenance issues

Contribution:

Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R., Research measurement of knowledge advances in building maintenance issues, *Structural Survey*, Vol. 32, Issue: 1, pp. 61-71, 2014, DOI: https://doi.org/10.1108/SS-08-2012-0023.

Research measurement of knowledge advances in building maintenance issues

Jorge Falorca
Collaborator of GEQUALTEC, Faculty of Engineering,
University of Porto, Porto, Portugal
R. Calejo Rodrigues
Department of Civil Engineering, Faculty of Engineering,
University of Porto, Porto, Portugal, and
R. Mendes da Silva
Department of Civil Engineering, Faculty of Sciences and Technology,
University of Coimbra, Coimbra, Portugal Portugal.

Abstract

Purpose – The purpose of this paper is to assess the general progress of Building Maintenance knowledge, to ascertain the growth of the whole body of literary production, and to determine which research lines may require further development.

Design/methodology/approach – Using several means of support, a detailed survey of over 2,000 titles of publications was made. The survey data were grouped into six pre-defined bibliographic indicators. The survey results were gradually organized into a database and MS Excel features were used for the subsequent process of counting and statistical analysis.

Findings – The results allowed the authors to develop an approximate growth model of the literature and provided indications of possible gaps in the development of knowledge.

Research limitations/implications – To allow for a more extensive analysis of the problem, this study was structured differently to a traditional literature review.

Practical implications – This study offers an overview of the evolution of building maintenance literature to researchers and institutions. A dynamic bibliographic database was also created which could be useful for those who perform management functions.

Originality/value – The approach of this study differs from other known studies in the area of building maintenance. This study releases an approximate measurement of advances made in the knowledge of a particular subject.

Keywords: Research, Bibliometrics, Building maintenance, Projections, Agenda.

Paper type: General review.

1. Introduction

All over the world, particularly in many developed countries, the Building Maintenance theme has required increasing attention from both researchers and public entities, mainly due to the growing number of existing buildings which rarely meet scheduled preservation actions.

In the last years, some authors, such as Ad Straub (2009), Mendes Silva and Falorca (2009), Flores-Colen et al. (2011), Kwon et al. (2011), Lateef et al. (2011), Taillandier et al. (2011), among many others, have given substantial attention to this subject with valuable contributions to the body of knowledge in this field. Also, in this sense, academic research is being developed in order to model an algorithm of integrated strategies for building maintenance management, to be implemented in a computer application. The first stage involved a comprehensive review of literature, with particular attention to the building maintenance theme. Making use of the subsequent global results, it was possible to thoroughly scan the state of knowledge, its evolution, and furthermore, to set up a dynamic bibliographic database, which could be particularly useful for anyone who performs management functions in that sector of economic activity.

This paper presents an evaluation of this branch of knowledge, based on several research studies, surveys and on a bibliographic systematization of different aspects. The objective is to further identify how building maintenance knowledge has globally developed in recent decades and how it can contribute toward the resolution of emerging difficulties. For this reason, a research measurement of scientific and technical contributions was made, which enabled a clearer understanding of some quantitative and qualitative developments, as well as their performance. Further sub-topics of the main theme were identified and a critical review was undertaken thus verifying the importance of our line of research.

This diagnosis was achieved with the use of a methodological procedure and the background of the production of literature was limited to the end of 2011. It includes some pre-established stages and it was restricted by some conditions which are discussed in paragraph 2. This is followed by a synthesis of partial results for some target fields of publications (called Direct Indicators) and the most important features resulting from the overall assessment are then discussed in Section 4 in order to estimate an approximate growth model of the literature. Based on the methodology used, an overview of some subareas of research is also presented, which may still require development. The last paragraph covers the conclusions of the present study.

The approach of this study differs from other known studies in the area of building maintenance.

2. Survey methodology – stages

2.1 Definition of target indicators

During the construction and research process of the bibliographic indicators, some decisions were made, especially with regard to the procedures of recovery/collection, organization/processing and data analysis (Maricato, 2011). Thus, it is necessary to briefly present the methodological procedures performed during the research development. According to the same author, to analyse and study the scientific and technological production and their interactions, it is acceptable to use various indicators, documents and variables.

Depending on the objectives, it was then necessary to set limits for the body of the empirical analysis. This leads to our own methodological procedures being adopted and, for instance, the main indicators being named and grouped into Direct Indicators and Resultant Indicators.

2.1.1 Direct indicators

Direct Indicators are associated with the five pre-selected target fields of the common scientific production or publication types: books, journal articles, proceeding articles, thesis and dissertations and standards. Furthermore, it was considered a supplementary group and was named Other Scientific Documents, in order to include a lot of scattered documents often given less importance. In spite of this, many of them had outcomes from working commissions and were even (co)-authored and edited by prestigious public and private organizations. They may be presented in the form of brochures, monographs, reports, papers, guidelines, among others.

2.1.2 Resultant indicators

Resultant Indicators are directly related to each Direct Indicator and represent several aspects which result from the numerical and statistical treatment of the survey. These can be the number of titles, the temporal distribution of titles found, occurrence of words or expressions, countries, languages, authors, meetings (events like conferences, seminars, workshops and others), etc. Table I summarizes the correlation between some of these indicators.

2.2 Data collection

It is also important to mention the basic assumptions of the study (type, time and space) and the main research fields used (supports).

For each Direct Indicator, the search and data gathering focussed exclusively on a survey of published titles of academic (or intrinsic) interest, namely for the study of the building maintenance theme and inserted within the context of the academic research in

development. It should be noted that the titles usually outline the main information of a work or identify the elements that characterize its contents (Ferreira, 2002).

Table I. Correlation between different indicators

	Direct indicators					
	Books	Journal articles	Proceeding articles	Other scientific documents	Thesis and dissertations	Standards
Main resultant indicators						
Number of titles	■	■	■	■	■	■
Temporal distribution	■	■	■	■	■	■
Countries	■		■	■		
Languages	■		■	■	■	
Occurrence of						
Words	■	■	■	■	■	■
Expressions	■	■	■	■	■	■
Publishers	■					
Authors	■	■	■	■		
Journals		■				
Organizations/ institutions			■	■		■
Meetings (events)			■			

Notes: The square blocks indicate the existence of correlation between different indicators

In order to provide a perspective of the full extent of the research as accurately as possible, the research was given unlimited space as well as time, up until the end of 2011. The research mainly focusses on titles written in languages recognized internationally and, in the author's, expertise.

Numerous means of support were used to carry out the collection of titles. The World Wide Web was the most extensively used mainly because it is used globally. For instance, several search engines such as Google, numerous links to institutional sites, journals, etc. were used. Using these resources, we could generate more accurate data and better organize the information. According to Smith (1999) and as referred to by Vanti (2002), search engines provide possibilities for the investigation of links or relations between documents similar to those offered by citation databases of ISI, so that an analogy can be established between the analysis of hyperlinks and the traditional analysis of citations in printed publications.

Almost every possible means to provide relevant information on publications related to the topic of study was utilized, including methods such as the query of diverse available literature and cross-checking information based on citations, references and so on.

2.3 Organization and data processing

The survey results were gradually organized into a database of titles for each Direct Indicator. For the subsequent process of counting and statistical analysis, MS Excel features

were used. Thus, it is possible to establish and to present a perspective of some partial results (for each Direct Indicator and some of its connected Resultant Indicator) and then discuss some of the most relevant aspects and carry out a comprehensive and conclusive analysis.

2.4 Research limitations

It should be noted that this type of research can involve some common problems: multiple authors can be removed or lost (through et al.), similar author's names using initials mixed with full names, fluctuation of influence and use and human error (typos), among others (Turnbull, 2000). An additional aspect also concerns the fact that it is common for some authors to have chapters in books. Although it may also be a non-countable mistake it is believed that this particular aspect can be considered negligible in relation to the results as a whole, mainly due to the volume of the sample. Furthermore, note that there has been a certain tendency to publish similar content in both journal articles and proceeding articles by the same authors, which is sometimes only distinguishable by small details. However, in the present study, it does not seem that these instances have substantial significance; and despite the possibility of their occurrence, they do not reduce the accuracy of the sample.

3. Synthesis of some partial results

3.1 Books

More than 400 cases were found as a result of the survey of books by relevance. An analysis of the distribution of publishing by countries and language shows that about 87 percent of the editions are written in English and the vast majority, about 46 percent, were published in the UK, especially England. The USA accounts for about 35 percent of the cases. Also, in an overview regarding the evolution of book titles available over time, it was possible to verify that those written in English have a growth similar to the overall availability. As is shown in Figure 1, there was a rapid growth trend of the quantity of books in the 1980s, which is virtually unchanged in the following two decades. From the 1990s, with the inflection of the edition of books in "other languages," there seems to be a growing tendency by the authors in general to publish in English, in detriment of the native language, possibly due to a natural requirement to globalize the development of knowledge.

3.2 Journal articles

The analysis had a higher incidence in international journals, covering more than 400 titles of journal articles considered with importance to this context. It was possible to verify that during the 1990s the number of this kind of publications had started to increase considerably. However, despite some annual fluctuations, an apparent tendency to stabilize in the 2000s can be seen. If we consider 1995 as the year when there was a relevant growth of published journal articles, we can verify a medium value of about 21 cases per year between 1995 and 2011. This could be illustrative of a considerable interest concerning the building

maintenance theme during this period. Basically, titles collected were published in reputable journals, most of them presented in ISI Web of Knowledge database.

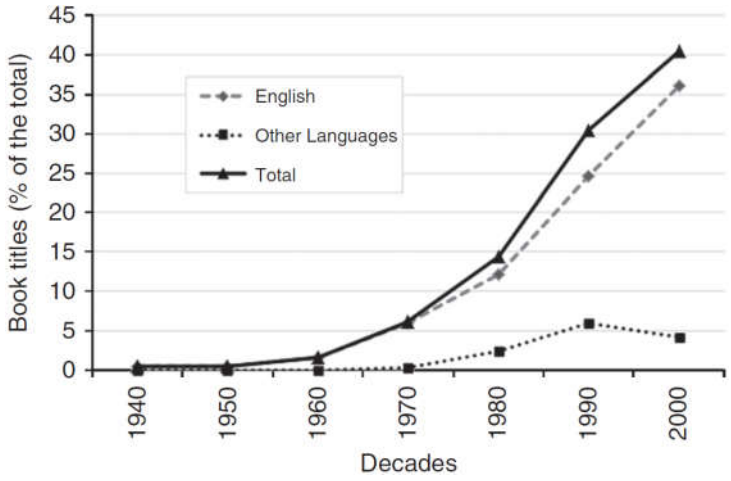

Figure 1. Partial results from the survey – availability of books per decade (in percent of the total)

3.3. Proceeding articles

In the last three decades, about 500 proceeding articles were identified, in a total of 170 international meetings performed in 40 countries. It is possible to distinguish two periods of growth related to this Direct Indicator. Between 1980 and 1997 a slightly accentuated increase was registered and thereafter a large growth of publications, although a substantial growth in the number of meetings has remained comparatively lower over the past decades – see Figure 2.

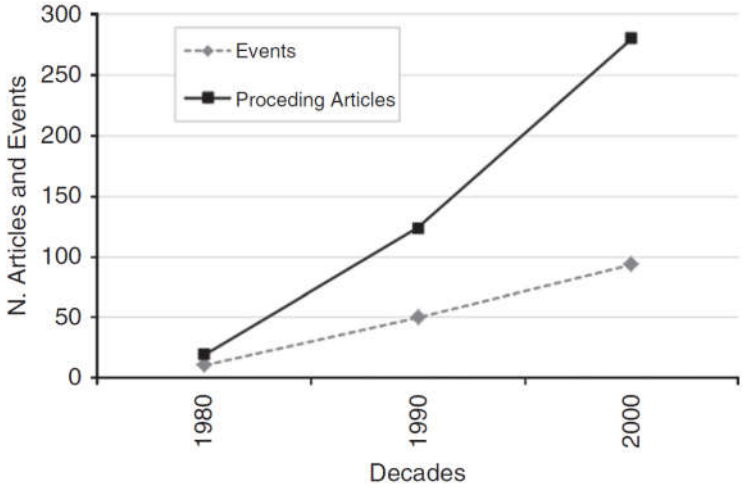

Figure 2. Partial results from the survey – sum of proceeding articles and events per decade

It is also worth noting the distribution of proceeding articles titles by events and its organizers; three main assembled groups can be distinguished. The first one, refers to different events organized by CIB (International Council for Research and Innovation in Building and Construction), mainly through the World Building Congress, to the seminars of

Working CommissionW070 and to another set called “Others of CIB,” which included several encounters. Together they seem to represent about 32 percent of the proceeding articles published. A second assembled group, with a total of approximately 36 percent, includes the international conferences on the Durability of Building Materials and Components (DBMC), the International Association for Housing Science (IAHS) – World Congress on Housing and the Euromaintenance. The last group called “Others”) corresponds to many other events around the world (32 percent).

3.4 Other scientific documents

Of these publications, about 450 relevant titles of documents published since 1960 were collected. The main results can be extracted from the information contained in: language used in publications; scope (of the subject cases selected and covered); and public institutions (co)authors and/or publishers.

Publications like “Report(s),” “Plan(s),” “Research” and “Manual(s)” were the most commonly found; the vast majority apparently originated in the UK (44 percent) and the USA (28 percent). It was also noted that texts written in English have seen a doubling in average growth for each of the last four decades, reaching a medium of 19 publications per year in the 2000s.

4. Overall results and discussion

4.1 The literature growth model

An integrated treatment of partial results allows us to get some global indicators and have a more comprehensive overview of the study, mainly in order to estimate an approximate growth model of the literature in this field.

Thus, this research identified a total of about 2,250 publications of interest through six Direct Indicators, with a temporal distribution as shown in Figure 3.

The analysis of line variation corresponding to the number of encountered titles per year, initially shows a gradual progression of publications over time, rising significantly at the end of the 1990s – a time where scientific production had increased significantly; and even at this high level has remained relatively stable in the last decade. It was noticed that the period between 1999 and 2011 corresponds to about 67 percent of total publications, with a medium production of about 116 cases per year.

The curve of the cumulative number of titles confirms that it was thereabouts in the mid-1990s that a notable inflection in the publications growth associated with the theme under study occurred.

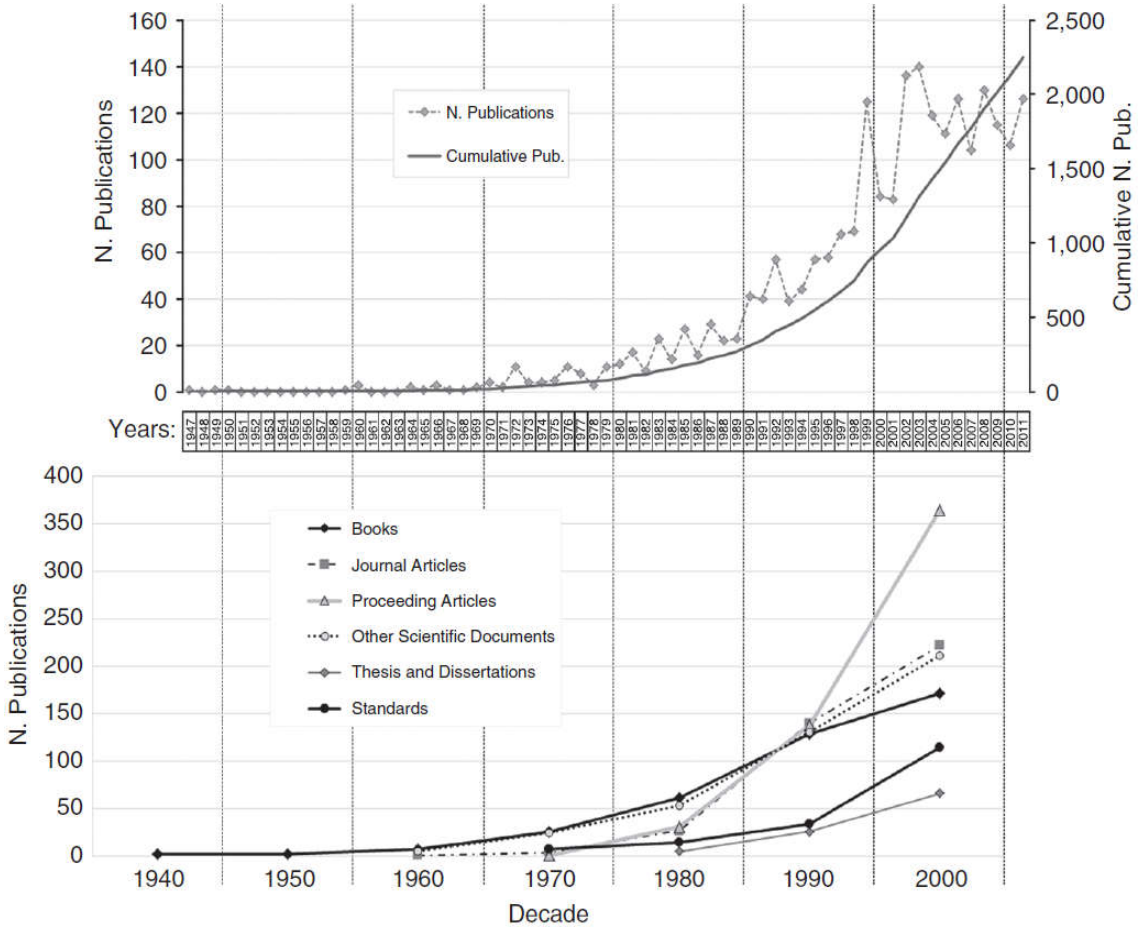

Figure 3. Research results – temporal distribution for the whole body of literary productions and by Direct Indicators

Also, an analysis of the lines connecting the cumulative values per decade enables us to see that there was a more or less regular growth of the different Direct Indicators, except for proceeding articles, which between the 1990s and 2000s had a substantial increase. The trend growth of books and other scientific documents seem to be analogous, which can be eventually explained by a certain similarity in these publications.

Moreover, data collected also allows us to present the best-fit line for the overall literature production and outline its growth tendency to a small period of five years. Thus, as is shown in Figure 4, although in the last decade the production of literature had been stabilized at higher values, it is supposed that in the next five years, the whole literature production will start a new growth stage, going to even higher levels than to those currently registered. So, for example, it can be estimated that in 2016, in the set of the six Direct Indicators considered in the present study, publications will probably reach about 150 units per year.

Even when an analysis of the growth behaviour among journal articles and proceeding articles is made, some similarities are found, although in the last decade a certain differentiation has occurred, as is shown in Figure 4, through its best-fit lines. This particular aspect can eventually reveal a greater interest within the scientific community over the last decade to

discuss their research work at regular meetings, instead of publishing in specialized journals, in which the exigency requested, may be higher. It is believed that until 2016, these Direct Indicators will initiate a slighter phase of growth.

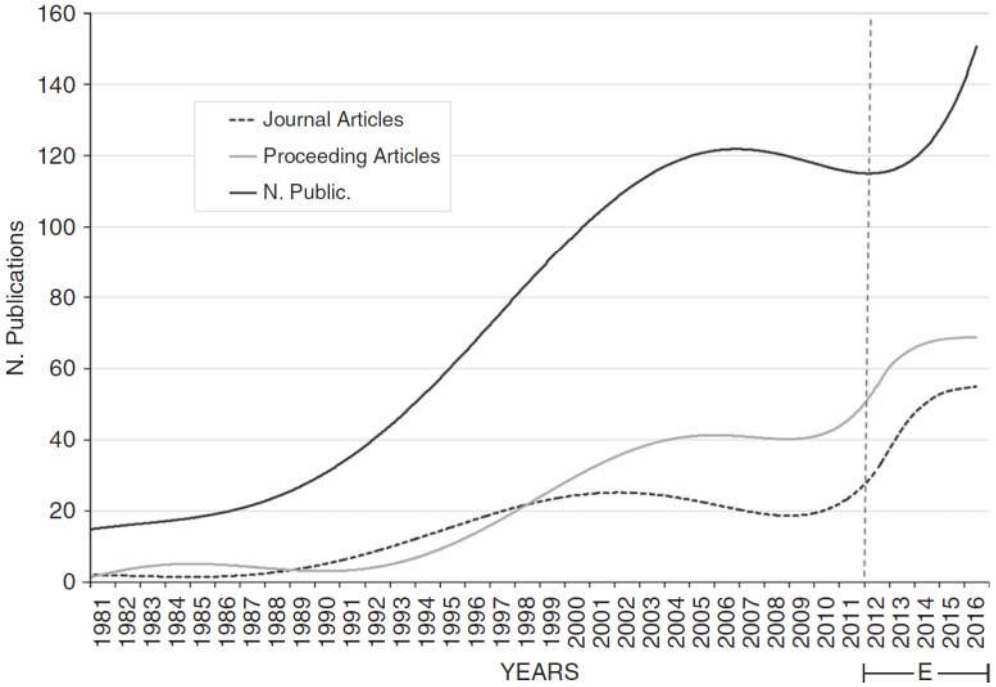

Figure 4. Best fit lines for the whole body of literary productions, for journal articles and proceeding articles and projections until 2016

4.2 Contributions for an improved research agenda

The outcomes of this kind of review could still make some other information available, even when considering eventual improvements in a research agenda. For that purpose, an additional task was performed to identify and analyse data output which could provide indications about possible gaps in the development of knowledge. In this context, the frequency of occurrence in all titles of a set of expressions and words closely related to the main area of study was verified, since it is believed that they can roughly represent the intrinsic range of research issues more or less studied. For example, Figure 5 presents the rate incidence of a set of 35 expressions used in a global sample of titles in English.

This graph shows some divisions to make it easier to interpret various different topics of interest. As a general overview, it can be seen that expressions with higher incidence in the collected titles are “Maintenance Management,” “Building Maintenance” and “Facilities Management” and the first three groups of expressions include words like “Maintenance” (or “Repairs” and “Conservation”) and “Manage(ment),” representing almost two-thirds of the total number of these occurrences.

A set of expressions like “Service Life,” “Life Cycle Assessment” (or “LCA”) and “Building Life” represent approximately 10.5 percent of the total, although in another ranking of 29

words searched in the titles, “Life” is the fourth with higher occurrence after “Maintenance”, “Building” and “Management.”

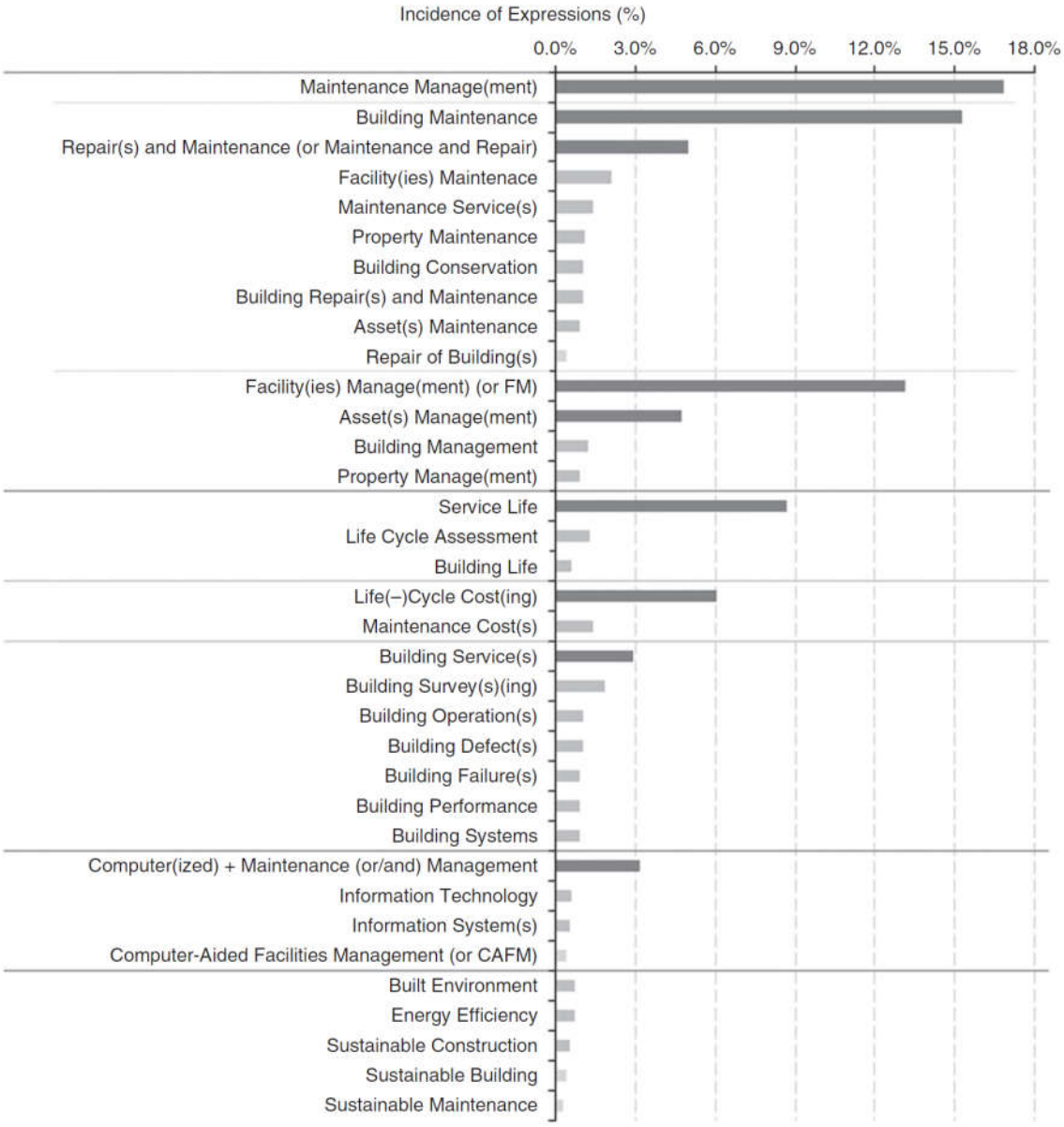

Figure 5. Incidence of several expressions in titles, relative to the set of occurrences

The group of expressions around the subthemes relating to computerized maintenance has an occurrence ratio of almost 5 percent, this may well represent one of the topics of greatest interest in recent times which can potentially increase. This also seems to confirm that our research line falls into important areas of study and may lead to an opportunity that can be successfully exploited.

It was also found that in the ranking of most popular words, “Performance” has one of the best scores, although the range of expressions containing it is not very representative. In addition, it was verified that a number of titles including words such as “Sustainability,” “Environment” and “Energy” appear, although some related expressions have low frequency,

as shown in Figure 5. Finally, was noted that there is both a relatively low frequency of occurrence of expressions and words like “Building Defect(s)” and “Building Failure(s)” as “Defect(s)” and “Failure(s).”

Although in this section an attempt has been made to obtain a perspective on the frequency of occurrence of some subtopics within the general scope of the research and related with the building maintenance theme, it is not inaccurate to say that some issues appearing here with a smaller apparent incidence, may not actually have increased coverage, if by chance, similar studies were conducted in other domains.

5. Conclusions

This paper has essentially focussed on a research measurement of bibliographies on the building maintenance theme. The results come from a methodology that follow a few steps, including the definition of target indicators to study, an in-depth survey of titles of a substantial number of publications and further organization and data processing. Partial results were presented by Direct Indicators in correlation with other so-called Resultant Indicators, followed by the discussion of some fundamental aspects of the overall findings.

As a whole, results seem to have some consistency, which can be regarded as a point emphasizing the accuracy of the survey, despite possible minor errors or related problems that can always be found in similar studies.

Some important outcomes obtained from research are then described. The first aspect to be highlighted regarding the Direct Indicators and in its composite treatment is that there is a common constant increase of publications over time, clearly reflecting a growing attention that has been given to building maintenance theme in general.

For this purpose, the most commonly used language is English and the majority of publications have Anglo-Saxon origin (the UK and the USA). Moreover, there seems to be a growing tendency to publish scientific work in English, with the aim of further viewing and the globalization of knowledge.

Also proceeding articles have registered a very sharp increase in recent years, very likely the result of an availability of funding for science and simultaneously a greater interest among the authors for this type of publication. Perhaps for these reasons, it was possible to notice a visible trend of a gradual increase in the ratio between the quantities of publications vs event rates.

A wide selection of titles of publications included in the Direct Indicator called Other Scientific Documents has provided an opportunity for gathering scattered information and subsequent analysis. This has allowed for the notion of an hierarchy of results, when the type

of covered publications (like report(s), plan(s), research(es), manual(s) and others already mentioned) was considered, while provides an idea about several institutions, especially public, which have sponsored many studies of this kind. Likewise, some of the most prestigious international journals have been an instrumental in the diffusion of knowledge, noting that the ratio of journal articles linked to several subjects within the building maintenance theme has increased considerably, above all in the last two decades.

In what is referred to as thesis and dissertations it was verified that, while there is a continuous growth of each type of academic publication, there is also an increasing distance between their relative growths, with a greater productivity of single cases of dissertations, namely for masters or licentiate degrees. Although there is a noticeably growing interest within the academic community to learn more about different subjects related to the building maintenance theme, this analysis also seems to show an increasing dropout of studies in this area after students finish their dissertation.

Finally, the overall results still allowed us to obtain an approximate growth model of the literature and at the same time provide some indications as to the possible gaps in the development of knowledge.

In conclusion, this study has made it possible to update overall knowledge regarding the main bibliographic indicators directly related to building maintenance, providing a comprehensive idea about the importance of academic research in development and giving an interesting and different contribution to the state of the art.

References

Ad Straub, (2009), "Dutch standard for condition assessment of buildings", Structural Survey, Vol. 27 No. 1, pp. 23-35.

Ferreira, N. (2002), "Research called 'state-of-the-art'", Educac¸˜ao & Sociedade, Vol. Ano XXIII No. 79, pp. 257-272 (in Portuguese), available at: www.propp.ufms.br/ppgedu/geppe/textoestadodaarte.pdf (accessed January 30, 2012).

Flores-Colen, I., Brito, J. and Freitas, V. (2011), "On-site performance assessment of rendering fac¸ades for predictive maintenance", Structural Survey, Vol. 29 No. 2, pp. 133-146.

Kwon, S., Chun, C. and Kwak, R. (2011), "Relationship between quality of building maintenance management services for indoor environmental quality and occupant satisfaction", Building and Environment, Vol. 46 No. 11, pp. 2179-2185.

Lateef Olanrewaju, A., Idrus, A. and Khamidi, M. (2011), "Investigating building maintenance practices in Malaysia: a case study", Structural Survey, Vol. 29 No. 5, pp. 397-410.

Maricato, J. (2011), "Methodological procedures in bibliometric and scientometric studies: options and considerations in the context of recovery procedures and information organization", in Costa, R. (Ed.), Contemporary Studies in Communications and Arts, Best Thesis and Dissertations of ECA/USP 2010, San Paulo, p. 19 (in Portuguese), available at: http://rabci.org/rabci/sites/default/files/Capı´tulo%20de%20e-book.pdf (accessed January 30, 2012).

Mendes Silva, J. and Falorca, J. (2009), “A model plan for buildings maintenance with application in the performance analysis of a composite facade cover”, Construction and Building Materials, Vol. 23 No. 10, pp. 3248-3257.
Smith, A. (1999), “A tale two web spaces: comparing sites using web impact factors”, Journal of Documentation, Vol. 55 No. 5, pp. 577-592.
Taillandier, F., Sauce, G. and Bonetto, R. (2011), “Method and tools for building maintenance plan arbitration”, Engineering, Construction and Architectural Management, Vol. 18 No. 4, pp. 343-362.
Turnbull, D. (2000), Bibliometrics and theWorld WideWeb, available at: www.ischool.utexas.edu/Bdonturn/research/bibweb.html (accessed January 16, 2012).
Vanti, N. (2002), “Bibliometrics to webometrics: a conceptual exploration of the mechanisms used to measure the record of information and dissemination of knowledge”, Ci. Inf., Vol. 1 No. 2, pp. 152-162 (in Portuguese).

3.2. Models and systems of maintenance management - a review to introduce a comprehensive information system for buildings

Contribution:

Falorca, J.,

Models and systems of maintenance management - a review to introduce a comprehensive information system for buildings, in: ICEUBI 2017, International Conference on Engineering, a Vision for the Future, 2017, December 5-7, University of Beira Interior, Covilhã, Portugal.

Models and systems of maintenance management - a review to introduce a comprehensive information system for buildings

Jorge Falorca; jorge.falorca@netvisao.pt
Jorge Falorca, Civil Engineer, MSc Construction Sciences.

Abstract

Particularly when it is seen in a structured way, positive developments have been registered in the building maintenance subject, which, however, needs to be increased. An important step towards that purpose is to reflect upon a set of experiences, typical of the maintenance field. This article summarizes a study carried out of bibliographic review on several models, systems and methods of maintenance management, both those with origin and application in industry in general, as well as the most important already developed and applied on buildings and built sets. Based in many of the theoretical aspects considered, the revision has contributed to draft an algorithm of procedures for a comprehensive information system with applicability on the management of real estate assets, whose project was generically called as SIAP(ME). In result of a comparative critical analysis, some aspects of the system convergence to some of the different topics reviewed are presented, as well the importance of its consideration for the effectiveness and value-adding innovation of this experimental tool, is also discussed.

Keywords: Building maintenance; review; models and systems; algorithm of procedures.

1. Introduction

Even though there is still much research to develop, it seems to be a consensus that there have already been made significant progresses around the building maintenance subject, particularly when it is seen in a structured way. However, there remains a widespread perception that, in general, many of the maintenance actions are reactive, with the main purpose of re-establishing the operational state of the elements and bringing back the normal utilisation of the buildings. While in the field of technical facilities and equipment, remains

the experience, the reviews and the manufacturer's recommendations as the most determinant aspects for type and frequency of maintenance operations needed, in the domain of the constructive elements, the introduction of such practices has been making considerable progresses, although still far from what would be desirable.

In this sense and because a basic activity of building maintenance management should not be performed in an improvised and casual way, it appears essential the emergence and development of contributions aimed at improving the real estate asset management methods, mainly through proper planning of processes and activities. Besides, it is important its implementation as had been planned, as well as by the evaluation of results, by triggering operations actions and improvement actions (in line with the needs) and by the integration of the information and knowledge, among other aspects. It should be noted that at present, the efficient use of information is a critical condition for the success for any organization.

Given the above considerations, it is believed that the best way forward can be through developing more studies and guidelines for the automation of procedures, scientifically well-founded. This may be the basis for new tools which make it possible to conduct a high-level of management in the building maintenance activity. And this is surely one of the pathways which will allow to this issue a more sustainable strategic development.

Thus, resulting of a research study recently carried out, an algorithm of a comprehensive information system for the management of real estate assets was drawn up. This project was generically called as Information System for Automatisation of Procedures in the Building Maintenance Management - initials in Portuguese: SIAP(ME). For that purpose, aspects of knowledge were firstly organized and structured (based on an extensive literature review) and among other aspects, one analysis of a wide range of models, systems and methods for maintenance management was considered. In this context, on the initial part of this text, briefly considerations to quite a few theories known as applied in the industrial maintenance area are made (for instance related with the WCM and others). Likewise, it is still considered a wide range of models and methods applied in buildings, as well some real cases for maintenance management and others at which the main assumptions are based on the assessment of buildings ’condition. The main objective of this analysis was to gather the available information, identify the advances in knowledge and bring into the functioning of SIAP(ME) most of those fundamentals. Section 4 describes succinctly the main features of the proposal for this algorithm.

Finally, resulting of a comparative critical analysis, the leading convergence aspects of the system comparatively to some of the different topics reviewed are presented and the importance to consider all for the effectiveness and innovation of this experimental tool is also debated.

2. Approaches in the field of industrial maintenance

2.1. Initial considerations

This step of the study basically consisted in the identification and analysis, over a substantial body of literature, of several models and procedures, which in general, have been studied, developed and/or used successfully in the industrial maintenance area.

It should be noted that the industrial organization is an open system, in which the raw materials are transformed into finished added-value products. In this context, the maintenance function aims to ensure the integrity of the fixed assets, particularly in the prospect to ensure the operational function of equipment. Until the first half of the last century, the maintenance actions were basically of reactive type (consisting of remedial actions, extensive reforms and large unscheduled interventions), performed mainly with the purpose of restoring a reasonable operational status of the equipment in which have already occurred failures. Over recent years, according to some authors [1,2], still remain the experience, the equipment's reviews and the manufacturer's recommendations as determining factors in relation to type and frequency of the maintenance operations. However, these have been undergoing changes, seeking a more sustainable action, based on provisions of services of higher value.

It is also worth noting that industrial maintenance is quite devoted to dynamic systems, in which the movement is a key factor of its behaviour, while building maintenance fundamentally deals with static systems, whose performance is highly dependent of aging phenomena and much less of dynamic efforts.

2.2. Brief comments on some models and procedures

The framework of this analysis does not exempt, for instance, a reference to the World Class Maintenance (WCM). According Biasotto [3], the need to establish parameters as a means of comparison between companies (Benchmarking), particularly aiming to occupy the place among the world's best, has led to the introduction of the WCM term. It is integrated in scope of the World Class Manufacturing, to describe a model that was new, different and effective for the maintenance function (which in this context embraces a strategic vision and contributing effectively to business results). Establishing itself as a strategic capacity to compete through the integrated management of assets, the WCM aims to achieve a high degree of competitiveness in its area of operation and enables companies to compete in any international market, using some key resources as the Maintenance Management Computerized System, the Operational Improvement, Reliability Centred Maintenance (RCM), Total Productive Maintenance (TPM), Continuous Improvement (CI) and Preventive and Predictive maintenance.

Still because of the knowledge development and application of innovative methods at the industry field, it was noted other interesting aspect, concerning the three main types of maintenance (preventive, predictive and reactive). In fact, there is a perception that companies have been increasingly focused on the adoption of preventive maintenance practices to the detriment of reactive maintenance.

3. Approaches in the field of buildings

3.1. Scope of the reviewed cases

In a second phase of the bibliographic review, it was analysed a wide range of methods and other procedures developed and/or used (or even with potential interest) in the buildings field, infrastructures or built sets. Figure 1 shows the generic scope for the most relevant situations.

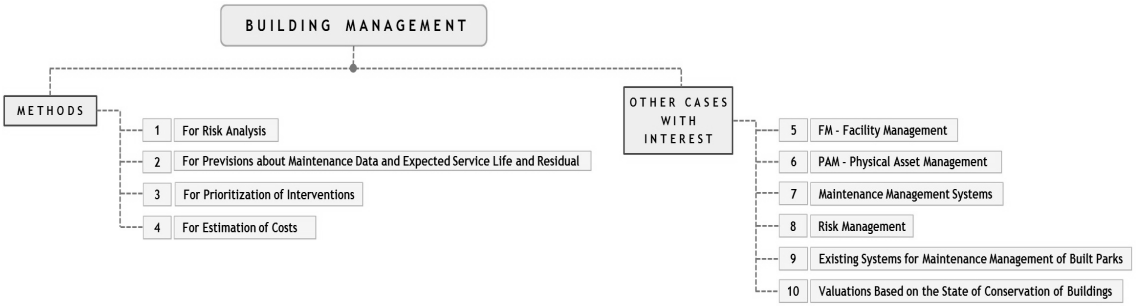

Figure 1 – Generic scope for models, procedures or methods developed, used or with interest in the building sector

3.2. The Physical Asset Management (PAM)

The Institute of Asset Management (IAM) - an independent organization for professionals dedicated to furthering the knowledge and understanding of Asset Management (AM) - together with the British Standard Institute (BSI) launched, in 2004, the BSI PAS 55 [4]. It is a Public Available Specification directed toward the optimizing of management of physical assets, describing AM as "systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan". Later, in 2008, the original BSI PAS 55 was reviewed and modified to reflect the views from the review panel sourced from a range of industrial sectors around the world. This standard was thus published in two parts: BSI PAS 55-1:2008 - Specification for the optimized management of physical assets [5]; and BSI PAS 55-2:2008 - Guidelines for the application of BSI PAS 55-1 [6].

PAS 55 is focused on all types of assets, varying from critical or strategic physical assets to human assets, positioned in four classes, including the real estate and facilities as offices, schools, hospitals [7]. Basically, it seeks to clarify the need for layered integration of what

needs to be done and its requirements are structured along the lines of Deming's Plan-Do-Check-Act cycle, in the same way as many quality management systems [8].

Since its publication in 2004, PAS 55 has been considered an international success case, since it is gradually known as a generically applicable definition of good practices in the optimized management of physical assets [9]. Consequently, in 2014, a new suite of AM standards describing AM and AM systems (ISO 55000/1/2) were published by the International Standards Organisation (ISO) and available through BSI [9,10], given those responsible for organizational governance and management an appreciation of why the organization should embrace AM and enunciates the benefits of AM and an AM system in providing a structured approach [11].

Also, the European Federation of National Maintenance Societies (EFNMS), has an active working group (the European Asset Management Committee - EAMC) dedicated to the study and concept application of AM. Its goals are basically to develop a conceptual model for an AM approach [12].

Still in this context, it is also available the CWA 16633:2013 [13] – a CEN Workshop Agreement (CWA), which is a reference document from the European Committee for Standardization (CEN), as the European Standard EN 16646:2014 [14], introducing PAM as a framework for maintenance activities.

Notice that it may be important to clarify the relationships between the PAM processes and maintenance processes. At this level, for instance, the scope of the EN 16646:2014 can help to understand this perspective better. Indeed, according to some available sources on this subject [15] the globalization and the increasing competition is presented as one of several reasons why over the past decades, the physical asset management and maintenance as part of PAM, became an essential point of the organizations' activities. Also, in the same line, PAM is also considered to establishes the necessary link between maintenance management and the organizational strategic plan, thus providing direction to the maintenance activities.

The role and tasks of the maintenance function within AM processes are also some of the highlighted aspects. From a basic understanding of some topics as available at [16], it should be stressed that the EN 16646:2014 defines PAM processes for the three levels of assets: the portfolio level, the asset system level and the individual assets; the role and tasks of the maintenance function have been determined at every stage of these processes. Likewise, four categories of roles of the maintenance function have been used within AM processes: informative, consultative, active and responsive. And so, it has chiefly reflected about the role and importance of maintenance within PAM system during the whole life cycle of an item.

3.3. Guidelines for building maintenance management systems

In the reviewing on the key attributes to pursue a well-reasoned and based Building Maintenance Management System (BMMS), it was analysed a structure similar to the set out in the framework document of the Department of Housing and Public Works of the Queensland State in Australia (QDHPW) [17], as well as a lot of aspects from important international standards, and many others as those reported by Silva [18].

Figure 2 represents the main policy requirements laid down by the DHPW for its maintenance management framework [17], and in this particular, similar objective for a suitable BMMS should ensure, as for instance, a continuous improvement in asset planning, maintenance procedures and risk management and that buildings are adequately maintained, with an assumption of a more strategic role in the maintenance of buildings.

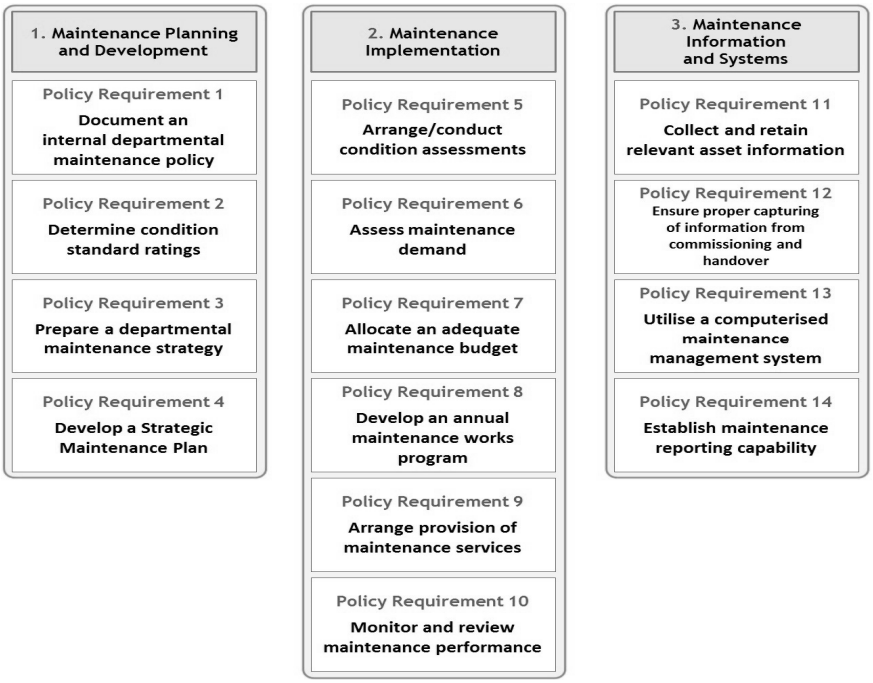

Figure 2 – Main elements/policies of the maintenance management structure foreseen by the DHPW (adapted from QDHPW [17])

3.4. Maintenance management systems developed for built sets

Some important cases of maintenance management systems with public purposes for built sets were identified. It was highlighted the Parque Escolar (PE) [19] - which is considered the most important model developed in recent years in Portugal - just like a few examples developed abroad, as those implemented in the university campus of the University of Savoy, France [20], in the U.K.'s school built sets [21], in the Victoria State in Australia [22] and in the U.K.'s social housing case [23].

It should be underlined that the PE model is focused in the planning, management, development and implementation of a public network modernization program for secondary

schools allocated to the Portuguese Ministry of Education. Its performance-based deals with the School Modernisation Programme aiming essentially to fulfil three objectives: re-qualifying and modernizing school buildings, replacing the physical and functional efficiency, opening the school to the community and creating a new management model of facilities, while ensuring optimization of installed resources and a proper building maintenance management [19].

In the study case started by Bonetto and Sauce [20] concerning the University of Savoy, it seemed there was an underlying intention to fill certain existing emptiness with the issue of information, mainly in the context and scope of asset management activities. Despite featuring a theoretical pending basically, the mapping of the real estate management activities defines an organizational structure that can be as well a reference to the management bodies and a framework for discussion and study on areas in which improvements can be made. The basis of an important sector of my model, ahead briefly presented, is also inspired in some key activities for management of built assets introduced by these authors, when putting forward another development framework better adjusted with our reality and present time as well with many other theories referred in this text.

3.5. Methods to assess buildings 'condition

The assessment of buildings 'condition (AB'sC) is fundamental into the building maintenance management or rehabilitation, as well as in the prioritization of interventions, in the determination of real estate value and in the appreciation of the economic viability of construction works. In recent years, this issue has been extensively studied at a national and international level, having emerged several interesting methods, many of which within institutional or legislative initiatives. One of the best known in Portugal is MAEC (in Portuguese: Método de Avaliação do Estado de Conservação de Imóveis), developed by the National Laboratory of Civil Engineering (LNEC) under the 2006 revision of urban rental regime [24]. In a simple way, this method allowed to determine the buildings' condition for purposes of updating of the rents of a dwelling unit by performing a visual inspection of the site by qualified technicians.

In addition to some other Portuguese methods, can still be referred the English method Housing Health and Safety Rating System (HHSRS) [25], the French method to assess the condition of buildings that may be declared inhabitable [26], the Dutch standard NEN 2767-1/2/3 [27,28,29] and the EPIQR (Energy Performance Indoor Environmental Quality Retrofit) and TOBUS (Tool for Selecting Office Building Upgrading Solutions) which were developed within European research projects. An interesting comparative and structured analysis of many of these methods was carried out by Vilhena [30] and Vilhena, Pedro and Brito [31]. Also, stands out several published contributions on this issue, as those from Balaras [32,33], Caccavelli and Gugerlib [34], Straub [35], among others.

4. Main features of the SIAP(ME)

4.1. Functional extension

In an abbreviated description, the organizational algorithm planned for the SIAP(ME) provides a functional amplitude which allows interactions between four sectors entities: the Management (General Administration) of the Organization, the Real Estate (Built Sets), the Outsourcing (Outside Staff and Services) and the Interaction between the system's User (see figure 3). The different steps of this model were being representatively conceived through the development of many organization charts with interconnections to each other and individually inserted in different sheets of MS Excel files. It was used, provisionally, this type of software because it was considered to be a facilitator to the progress and aggregate exposure of the idea, as well as to the realization of hierarchical graphical models.

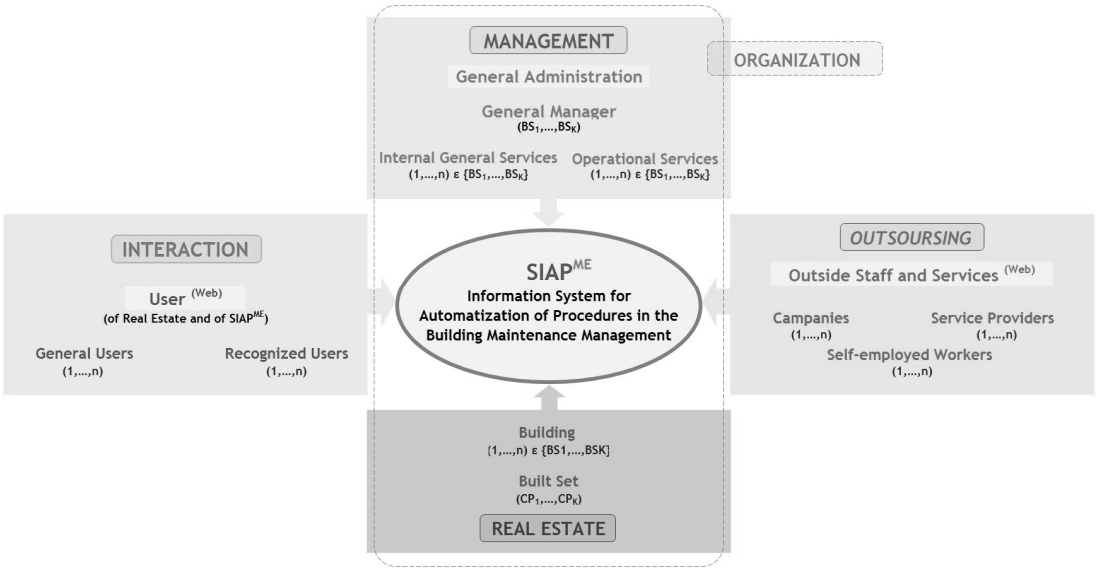

Figure 3 – Functional amplitude of the organizational algorithm in the SIAP(ME)

4.2. The system's principal core

By running the General Asset Management Functions option, the user will be at the core of the projected system and can view (with full or restricted access) those which were considered the six general functions for real estate management, covering virtually all the fundamental aspects of this activity (see figure 4).

5. Comparative critical analysis

To check the most important aspects of convergence of SIAP(ME) in relation to the wide range of reviewed subjects, a comparative critical examination was performed. The goal was to demonstrate that the proposed algorithm is a very comprehensive and effective solution and in fact it covers a lot of fundamental areas.

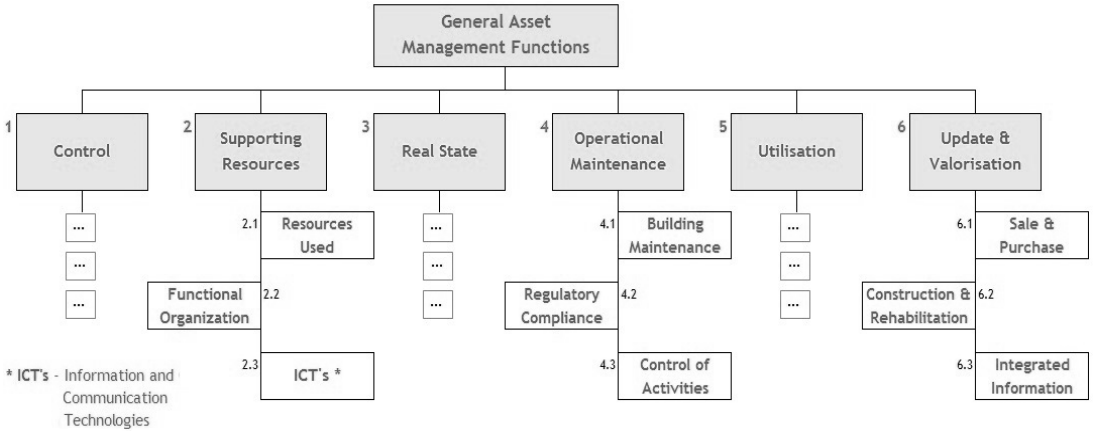

Figure 4 – SIAP(ME)'s principal core - some of the asset management functions and modules forecasted

Therefore, on this study it was scrutinized the convergence with many aspects of the building maintenance theory, with models and procedures used in the industrial maintenance as with those developed and /or applied to buildings - table 1 displays some cases. It was also carried out a comparative analysis with the main policies of the maintenance management structure foreseen by the QDHPW [17], with which many points of agreement were checked.

Likewise, a confrontation was made with all modules and sub-modules of the SIAP(ME) against the six cases of systems for maintenance management for built sets above mentioned. This scan has allowed corroborating that the SIAP(ME) is based on a distinctive set of guidelines and it has a broader base configuration than many similar cases.

Table 1 - SIAP(ME): aspects of convergence to some models and procedures used in the field of buildings

M.	Aspects of Convergence
FMEA / FMECA (Failure Modes and Effects - and Criticality - Analysis)	In its Knowledge module, the SIAP(ME) also provides the identification and prioritization of the different subsystems and components constituting the system to be studied. In the case of the Reference State Characterization (RSC) and in the Inspection Event Sheet (IES) is provided a simulation / verification of the criticality, as well as a set of Recommended Actions and its Prioritization. To each building component, in the category of Other Characteristics, it is suggested the association of a Potential Failure Mode (PFM) by assigning an individual code. Also, at the Manuals (Technical Documentation), it is projected the inclusion of PMF's for each building subsystem.
FM	The SIAP(ME) is intended to be like a FM system, since it pretends to fully satisfy the property management and the support services of the Organization, meeting the general aspects of FM definitions and goals. The system also foresees that the Organization be established according to a hierarchy (management levels).
PAM	The SIAP(ME) might resemble a PAM system, since its general outlines conform to the definition of AM. In addition, the system intends to be an integrated approach, based on a holistic, optimized and sustainable analysis of the physical assets which it considers. Overall, the functioning of SIAP(ME) also aims to be based on the general principles of the PDCA methodology, i.e., plan, do, check and act.
AB´sC	In the Descriptive Information Management of the Real Estate, in the option of the Building General Data, the SIAP(ME) provides alternatively for recourse to MAEC method and to the one stated by the QDHPW.

6. Final discussion and conclusions

In a first step, this article briefly presents a review on a set of methodologies which assist the maintenance management activities, both in classical strand and context of the industrial management, as well as through an introspective to several cases already used or considered with potential utility in the buildings' sphere.

The interest of getting from the industry different concepts and the knowledge on its steady progress, comes from the fact that there are many features with great potential of adapting to BMMS's, as even most recently, there are already researchers considering many of its key concepts inside their research field, although often this desideratum can still be achieved in a tenuous or experimentalist way.

As to the industrial maintenance takes particularly interest in the safeguarding of parts and equipment to ensure its proper functioning and consequently, to produce products with maximum profitability; in buildings spectrum, there is also a preservation concern regarding its different elements, making use of advantageous operating methods, seeking the maximum longevity and the well-being of users.

Industrial maintenance uses techniques which are constantly changing under a compulsion of a continued investment in its development, being that many of which are already well advanced. Thus, it can be advantageous for those who look into the building maintenance issue, to retain some domain in this field and perhaps apply the resulting knowledge (in the extent of the necessary adaptations), particularly when studying ways to perform integrated maintenance models, easily applicable, regardless of the size of the building or group of buildings, and simultaneously conferring maximum utility in the context of current preservation needs of both managers, built sets, condominiums, etc., as to the common user.

From a comprehensive and wider analysis, such as that performed, it is feasible to draw several conclusions and take many aspects of great utility; however, it was drawn attention for just a few, owing to the scale and general nature of this text. Even so, it might be noted that in the industry case and at the level of the most demanding companies, maintenance already follows top standards, designated as World Class, making use of different means, as Computerized Maintenance Management Systems (CMMS), the Continuous Improvement, and others. A cross-cutting issue throughout this sector of activity has been the growing and widespread option for the use of preventive maintenance.

Around the methods applicable or already used in buildings, stands out the introduction of risk analysis and the most current fundamentals about its management, as well other essential aspects, yet most studied, resulting from the forecasting methods of maintenance dates and estimated lifetime, from the prioritization of interventions and cost evaluation,

etc. It was also highlighted the latest developments on the concept of Asset Management and the growing interest around the concept of Facility Management.

Perhaps one of the most incisive aspect arising from this review was to detect that there has been progress in appropriate policies requirements for the implementation of BMMSs, mainly based on some more advanced cases from the Anglo-Saxon domain, on some regulatory guidelines of high quality and on certain examples resulting of a first-rate academic research.

Still as a further matter coming from the application of many of the concepts above referred, a draft of an algorithm of a comprehensive information system for the management of real estate assets was presented. This project was generically called as SIAP(ME) and its ambitious goal is to serve as a well-founded strategic basis for the development of an own software solution. It was thought to contribute for the simplification of the functional performance of any organization (regardless of its size), based on an innovative design, comprehensive and integrative of all information, perhaps more than many existing programs, even those classified in the CMMS category or from another sort. Some others advantages of SIAP(ME)'s model may also be mentioned: a) a future transformation into a software solution will allow its decomposition into basic modules for a more personalized management of a building or built sets (and even be perfectly adjusted to the management needs of a maintenance manager); b) it will allow a clear and detailed demarcation of the Manager's functions and guidelines, by defining a wide range of aspects that are not generally taken into account in other solutions; c) it will be possible for the General Manager to define a strategy and to measure and control its own performance; d) it predicts Balance Sheet(s) for each activity; e) it will permit full control of all Elements of the Building(s), through a Cadastre/Attribute Trees; f) it will provide automatic mechanisms of reaction and operationalization of maintenance inspections; g) it forecasts to cover the exploration of all buildings, with the management of the spaces allocation, and as well, embracing a very detailed GTIC (Technical, Intelligent and Centralized Management) for Energy Management, Energy Efficiency, Comfort and Sustainability, Renewables Resources, Services & Routines, etc. A relevant disadvantage can be linked with the innovative nature of some aspects which, in so far as they had never been materialized and applied in practice, may carry out added difficulties for its subsequent operationalization. Other details about SIAP(ME) can be found in other companion paper (proceedings of the ICEUBI2017).

At last, the work accomplished to check the integration of many points of convergence with the wide range of reviewed subjects allowed, on one hand, to have an idea about the importance of knowing in some depth the general state of the current knowledge; and on the other hand, based on this, to give sense to a proposal for an algorithm such as the one introduced, mainly in terms of effectiveness and innovation of its own programmatic content.

References

[1] Tsang, A.: “Strategic dimensions of maintenance management”, Journal of Quality in Maintenance Engineering, Vol. 8 Issue: 1 (2002), pp.7-39.

[2] J. T. Lima: Gestão da manutenção industrial e medição de desempenho em uma indústria petroquímica: estudo de multicaso. Dissertação de Mestrado em Gestão e Tecnologia Industrial, Faculdade de Tecnologia SENAI CIMATEC, Salvador, Brasil, 2002.

[3] E. Biasotto: Aplicação do BSC na gestão da TPM - Estudo de Caso em Indústria de Processo. p. 170. Dissertação de Mestrado em Engenharia Mecânica, Universidade Federal de Santa Catarina, Florianópolis, Brasil, 2006.

[4] BSI PAS 55-1:2003, Asset management. Specification for the optimised management of physical infrastructure assets, British Standard Institute, London, U.K. Information taken from: http://shop.bsigroup.com/ProductDetail/?pid=000000000030077936 (09/05/2016)

[5] BSI PAS 55-1:2008, Specification for the optimized management of physical assets, British Standard Institute, London, U.K. Information taken from: http://shop.bsigroup.com/ProductDetail/?pid=000000000030171836 (09/05/2016)

[6] BSI PAS 55-2:2008, Guidelines for the application of PAS 55-1, British Standard Institute, London, U.K. Information taken from: http://shop.bsigroup.com/ProductDetail?pid=000000000030187096 (09/05/2016)

[7] IBM Corporation, Enabling the benefits of PAS 55: The new standard for asset management in the industry. https://www-935.ibm.com/services/uk/bcs/pdf/090622_pas_55_white_paper_6815_tiw14035usen00_final.pdf (10/07/2017)

[8] IAM, Structure of PAS55 Requirements, The Institute of Asset Management. https://theiam.org/knowledge/diagrams/structure-55-requirements (09/05/2016)

[9] BS ISO 55000:2014, Asset management. Overview, principles and terminology, British Standard Institute, London, U.K.. Information taken from: http://shop.bsigroup.com/ProductDetail/?pid=000000000030300420 (09/05/2016)

[10] IAM. The self-assessment methodology plus - Version 2.0. The Institute of Asset Management, 2015. https://theiam.org/system/files/privatedownloads/1/iamselfassessmentmethodologyplusv12pdf.pdf (09/05/2016)

[11] NAMS, IPWEA. Supplement to the IIMM 2011 - Quick guide: meeting ISO 55001 requirements for asset management - Using the international infrastructure management manual (IIMM). New Zealand National Asset Management Support Group (NAMS) and the Institute of Public Works Engineering Australasia (IPWEA), 2014.

[12] EFNMS, Asset management committee strategy presentation, European Federation of National Maintenance Societies, Brussels, Belgium. http://www.efnms.org/consoleo_files/modulefiles//filebrowser/images/committees/EAMC_Presentation.pdf (09/05/2016)

[13] CWA 16633:2013, Ageing behaviour of structural components with regard to integrated lifetime assessment and subsequent asset management of constructed facilities, Comité Européen de Normalisation, Brussels, Belgium. Information taken from: http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:40010,835883&cs=1EA320F0B46D4C3FD9F5FB2865C3ADCF4 (09/05/2016)

[14] EN 16646:2014, Maintenance - maintenance within physical asset management, Comité Européen de Normalisation, Brussels, Belgium. Information taken from: http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:36065&cs=17970B398228BD06B4FD6501AAD28110F (09/05/2016)

[15] BS EN 16646:2014, Maintenance. Maintenance within physical asset management, British Standard Institute, London, U.K.. Information taken from the Click to Preview on: https://shop.bsigroup.com/ProductDetail/?pid=000000000030284862 (30/10/2017).

[16] Komonen, K. Maintenance within physical asset management. http://www.sfsedu.fi/files/269/SFSEdu_EN16646_opetusmateriaali_7.0_english.pdf (30/10/2017).

[17] QDHPW. Maintenance management framework. Policy for the maintenance of Queensland Government buildings, Revised 2nd Edn. Queensland Department of Housing and Public Works, The State of Queensland, Australia, 2012.

[18] S. C. Silva. A Gestão da atividade de manutenção em edifícios públicos – modelo e definição de estratégias para uma intervenção sustentável. Tese de Doutoramento em Engenharia Civil, IST, Lisboa, Portugal, 2011.
[19] PE, Portal Parque Escolar. http://www.parque-escolar.pt/pt/programa/objetivos.aspx (09/05/2016)
[20] R. Bonetto, G. Sauce: Gestion de patrimoine immobilier. Les activités de references. CSTB, Université de Savoie, France, 2005 (referred by [18]).
[21] DfEE. Asset management plans. Section 1: Framework. Department for Education and Employment (DfEE) Publications, London, U.K. 2000.
[22] Smith, J.; Stewart, P.: "State-wide schools' maintenance audit in Victoria, Australia: the framework and process", Structural Survey, Vol. 25 Issue 1(2007), pp. 24-38.
[23] Cooper, J., Jones, K., Routine maintenance and sustainability of existing social housing. CIB W070 Conference in Facilities Management, Edinburgh, U.K., 2008.
[24] MOP, LNEC. NRAU - Método de avaliação do estado de conservação de imóveis - Instruções de aplicação. Ministério das Obras Públicas, Transportes e Comunicações e Laboratório Nacional de Engenharia Civil, Lisboa, Portugal, 2007.
[25] ODPM. Housing health and safety rating system. The Office of the Deputy Prime Minister, London, U.K., 2006.
[26] MSFPH. Circulaire DGS/DGUHC/SD7C/IUH4/293 du 23 juin 2003. Ministère de la Santé, de la Famille et des Personnes Handicapées, Paris, France, 2003.
[27] NEN 2767-1:2006, Condition assessment of building and installation components - Part 1: Methodology, Netherlands Standardization Institute, Delft, Netherlands. Information taken from: https://www.nen.nl/NEN-Shop-2/Standard/NEN-276712006-nl.htm (15/03/2017)
[28] NEN 2767-2:2008, Condition assessment of building and installation components - Part 2: Lists of faults, Netherlands Standardization Institute, Delft, Netherlands. Information taken from: https://www.nen.nl/NEN-Shop-2/Standard/NEN-276722008-nl.htm (15/03/2017)
[29] NEN 2767-3:2009, Condition assessment of building and installation components - Part 3: Aggregation of condition scores of Technical Index, Netherlands Standardization Institute, Delft, Netherlands. Information taken from: https://www.nen.nl/NEN-Shop-2/Standard/NEN-276732009-Ontw.-nl.htm (15/03/2017)
[30] A. Vilhena. Método de avaliação do estado de conservação de edifícios. Tese de Doutoramento em Engenharia Civil, IST, Lisboa, Portugal, 2011.
[31] Vilhena, A, Pedro, J., Brito, J., Comparison of methods used in European countries to assess buildings' condition. XII DBMC, Porto, Portugal, 2011.
[32] Balaras, C. (Ed.): "A special issue devoted to EPIQR", Energy and Buildings, Vol. 31 No. 2 (2000).
[33] Balaras, C.: "TOBUS - A European method and software for office building refurbishment", Energy and Buildings, Vol. 34 Issue: 2 (2002), pp. 111-112.
[34] Caccavelli, D.; Gugerlib, H.: "TOBUS – a European diagnosis and decision-making tool for office building upgrading", Energy and Buildings, Vol. 34 Issue: 2 (2002), pp. 113-119.
[35] Straub, Ad.: "Dutch standard for condition assessment of buildings", Structural Survey, Vol. 27 No. 1 (2009), pp. 23-35.

3.3. Lean building maintenance – proposal for a conceptual approach

Contribution:

Falorca, J., Calejo Rodrigues, R., Mendes da Silva, R.,

Lean building maintenance – proposal for a conceptual approach, in: ICEUBI 2013, International Conference on Engineering, Engineering for Economic Development, 2013, November 27-29, University of Beira Interior, Covilhã, Portugal.

Lean building maintenance – proposal for a conceptual approach

Jorge F. Falorca[1] / R. Calejo Rodrigues[2] / R. Mendes da Silva[3]
[1] Civil Engineer, MSc Construction Sciences, Covilhã, Portugal,
[2] Auxiliary Professor, Faculty of Engineering of University of Porto, Portugal
[3] Associate Professor, Faculty of Sciences and Technology of University of Coimbra, Portugal
jorge.falorca@netvisao.pt, calejo@fe.up.pt, raimundo@dec.uc.pt.

Abstract

The Building Maintenance Management (BMM) is a successful business, as has been perceived by a growing number of companies working in this sector, by the wider use of some supporting tools and by substantial research work developed in the meantime. Companies are forced to work in more advanced and efficient environments, and have to make regular improvements to the asset management methods. Originating from the Manufacturing Industry, the Lean concept incorporates a set of tools which can be useful in such a way. As a result of a literature review, this article identifies several aspects which may contribute to the improvement of tasks in the BMM. The essential Lean features are applied to a generic BMM process (BMMP), whose practice is proposed to be known as Lean Building Maintenance. The results highlight the procedures agility, in order to reduce or eliminate usual waste and are viewed as an important stimulator to any comprehensive software update within the BMM, as well to assist the development of new and efficient related tools. The Information Systems dedicated to buildings service behaviour involving a Lean view, end up having a specific identity.

Keywords: Buildings; Lean; Maintenance; Management; Optimization; Waste Management.

1. Introduction

It is known that activities underlying the Building Maintenance almost grow together with the developing of the nations and in many cases have already reached about half of the Construction activities of the most advanced industrialized countries. Despite still being an increasing area of activity that uses its own methods, it is already dealing with situations and customers with greater demands who are seeking more efficacious services of higher quality

and speed, without this involving a rise of costs. Hence the need arises to seek innovations that contribute to the improvement of its performance as a way of acting. Therefore, the use of Lean concept cannot be neglected, particularly in studies aiming at those objectives.

This article seeks to discover how we can introduce and use the Lean's principles in the BMM phase and verify what kind of practical use and utility can be drawn from these theories. With this in mind, an overview about the Lean concept has previously been made, focusing on key points of the state of the art which may have interest to improve the applicability of involved processes (or to develop), towards a proper BMM.

The analysis of the current situation point does not exempt one reflexive research on the latest principles in use in Construction sector, derived from the Lean philosophy. This approach is fundamental to better understand different aspects which can be useful to its applicability within the BMM field. In this way, the research question is then situated, also taking into account the advances that have recently taken place in Lean Construction (LC), mainly with regard to some introduced tools and relevant empirical knowledge developed. Purposing yet to foresee a solid base of Lean's use, a practical application is then presented, aiming to integrate important concepts distinguished as adaptable to a common BMMP. In this case, the main waste related problems are listed with the empirical knowledge acquired, and at last, a conceptual proposal for the integration of the Lean concept into the building's long-term phase is presented.

From a scientific methodological point of view, this study is fundamentally seen as theoretical research, in which the collected knowledge is used to formulate a practical application in order to solve current problems of modern life. The problem is approached in a qualitative and descriptive way, although the analysis of relevant control cases is resorted to (as the example of empirical studies which can offer good ideas about the usefulness of these concepts). Regarding the objectives, this work is also an exploratory study, since it provides greater familiarity with a problem through a literature procedure. Furthermore, from a theoretical perspective, it intends to extend some generalizations and organizes a theoretical model through a hypothesis, to see the problem.

So, the compilation of a large amount of information, its treatment and the emphasis given to several strong points, is useful to the consolidation of new methodology procedures, above all in what concerns inter-relational flows within a modelling algorithm of an Information System to automatize the BMM procedures, such as those under development by the authors.

2. Positioning the Research Question

2.1. Flows in Construction

Lean is a philosophy from which methods, techniques and tools have been developed. The word Lean comes from Old English, meaning, thin, and to be Lean is also perhaps to be fast and agile. A Lean system is briefly seen as an efficient state in constant evolution. In Portuguese, this word is also commonly mentioned as 'magro' (meaning free fat) and tries to reflect a factories many reductions: reductions of human effort, production space, investment of manufacturing and tools, and time taken to engineer, design and develop new products.

As is known, the Lean philosophy has already been applied in different areas, such as Airlines, Restaurants, Health and Construction. In this context, the current research question needs to be situated. As such, we can't separate its subject matter from within the Construction scope in general, since it is also reflected as part of it. However, it is also recognized that the Construction sector is complex and diverse, covering different stakeholders performing in different stages of an enterprise [1]. The use of Lean in Construction is necessarily preceded by the knowledge of its flows, which according to Womack [2], as cited by Picchi [3], are the following:

- The Design Flow (from conception to customer);
- The Building Flow (from construction order until delivery, from the raw material until delivery);
- The Support Flow (over the lifetime until recycle).

Taking into account the different stakeholders, Picchi [3] also suggested a terminology for flows in the Construction sector (Figure 1).

The Use and Maintenance flow (behind considered as the Support Flow) is essentially led by Maintenance companies and is considered to start after the construction delivery, involving the use, operation and maintenance, repairs, remodelling and demolition.

2.2. Lean Construction

The propose of the current study does not exclude the positioning of the research question whilst taking into account the specific area of LC, since in the meantime this subject has gathered increasing interest and investigation by the scientific community and may help us to better frame the problem.

The LC's first references emerged in a technical report by Koskela [4], which defied the Construction community to consider the consequences of the disabled dynamics of time-cost-quality. In 1993, LC expression was formalized and registered by the International Group for

Lean Construction and gradually has become a well-established theme on the Construction agenda of some countries, such as in Denmark and the U.K. But in the LC case, two major approaches can also be seen: one is defining new methods of management for the Construction Industry based on Lean Thinking and other is trying to adapt the methodologies of Lean Production into this sector. Thus, the LC can be a way to design and build based on Lean Production, in order to maximize value and minimize waste, finding at the same time the balance between time, cost and quality in the Construction sector [5]. Note that the main sources of waste in Construction, mainly in the phases of design and production, are the use of further resources than necessary, further consume of time than needed, excess of inventories and information, incorrect or incomplete instructions and labour forces with poor performance [6].

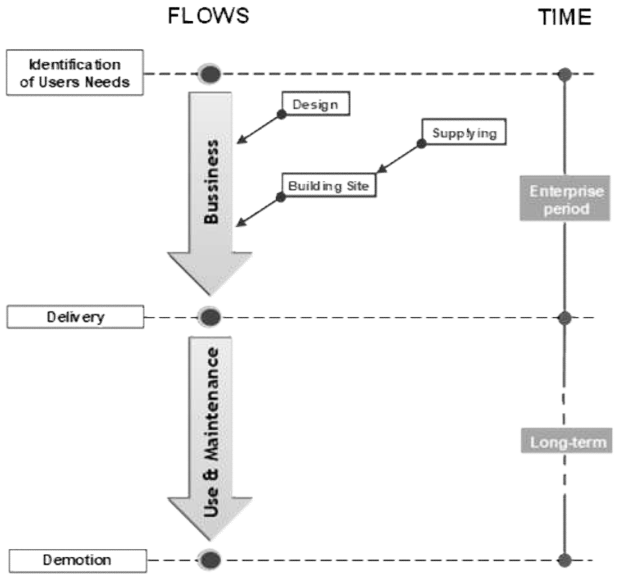

Figure 1 – Construction flows (adapted from [3])

Nevertheless, the use of LC is also somewhat conceptual. Even so, there are already some tools (or methodologies) which embody these principles.

The Last Planner System (LPS) is one of the most important tools of LC [7, 8]. Its procedural methodology was formalized in the doctoral thesis of Ballard [5] and further improvements had been developed in the Lean Construction Institute. The LPS is a system of planning and control of production, seeking to smooth the work flow variations, develop highly predictable schedules and to reduce operations with an uncertainty factor.

Similarly, BIM is another recent and widely used tool. Even though LC is a conceptual approach to the project management and construction, BIM is a transformative information technology. It embodies the production processes and information management during the life cycle of a construction [9,10]. The most common applications use a three-dimensional model of building as a repository for dynamic integration of its information [11]. According to

Sacks et al [12], while both tools are conceptually independent and separate, there appears to be synergies between them, extending beyond the essentially circumstantial nature of their contemporaneously approaching maturity.

A brief literature review on LC, also allowed us to perceive that studies are commonly performed in the basis of empirical approaches. With a sense to collect further useful outlooks, Table 1 presents a brief scope overview and findings of some control cases covering quite a lot of aspects in discussion on LC in recent years. Jointly with the importance brought with this literature to greater comprehension about the research question, it served likewise to illustrate a certain dispersal of matters in which the recent debate on LC has been done.

So, basically, with reference to the fundamentals stated in Figure 1, the LC seems to fit into the flow area of Business - including Design Flow and Building Flow according to Womack [2] - meaning reducing waste in Construction processes, including project design, planning and control of activities, supply chain, resource management and in the interface with the consumer. Following this, it makes sense that the idea put forward to be introduced and designated as Lean Building Maintenance (LBM), can be framed in the Use and Maintenance flow – or Support Flow in agreement with Womack [2].

As the LBM is a poorly discussed and studied theme, it seems reasonable that its development could be achieved by using some important aspects of the knowledge from the LC practices.

2.3. Developments in the Perspective of the Building Long-Term Period

Beyond the implementation of the Lean philosophy into the buildings construction phase, mainly focusing on LC, still remains some difficulty in finding studies applying Lean tools in the Building Maintenance stage. For instance, a conclusion of Picchi [3], mentions that very few studies have been found to apply the Lean philosophy to the flow of Use and Maintenance.

However, in a recent thesis carried out by Salermo [20], a concrete application of the Maintenance Services with the Lean Thinking tools and the Autonomous Maintenance has been attempted. Table 2 tries to summarize specific aspects accomplished by this adaptation to the Building Maintenance phase.

Throughout the development of current research we sought to analyse other studies which apply Lean to the Use and Maintenance flow, but this proved unsuccessful. This in fact can lead us to conclude that this specific issue seems to be in an early development stage. And indeed, our integration proposal can also be seen as exploratory research.

Table 1 - Some cases of empirical studies on LC – a brief scope overview

Author(s)	Purposes	Findings / Conclusions
AlSehaimi *et al.* [13]	Evaluates the effectiveness of implementing LPS to improve construction planning practice in Saudi Construction Industry.	The results demonstrated numerous benefits were gained in terms of improving construction planning and site management.
Gonçalves [14]	Proposed the introduction of principles and concepts related to the LC system in a Portuguese company, analysing the reality of the management system in place and the opportunities for improving the company's production process.	It was highlighted that the integration of LC principles makes the improvement of the production system and the spread of good practices in the construction system possible, with simple implementation techniques.
Jacobs [15]	Aligns with the International Group of Lean Construction (IGLC) conference proceedings against the Toyota Production System[1] (TPS) to determine how well research themes in construction studies align with the TPS framework.	The analysis revealed that Lean research in Construction did not align exclusively around the TPS framework. From 592 studies, 241 (40%) were classified within the four overarching TPS categories having the 14 TPS principles; 351 (60%) were classified outside the framework as fitting in one of 15 other important proxy Lean related research categories.
Seppanen *et al.* [16]	The LPS and the Location-Based Management System (LBMS) both aim to achieve the Lean goals of decreasing waste, increasing productivity and decreasing variability. The purpose was to develop a process and best practices to combine the benefits of LPS and LBMS.	By combining the systems, schedule conformance should increase, project durations should shrink, productivity should be further increased and cascading delay chains should show a decrease. Although the hypotheses will be evaluated in future research.
Golyani [17]	Studies how the information handling affects the value delivery for construction projects. This was done by nine face-to-face interviews conducted with managers of Construction companies active in Sweden and all along that a literature review was done to fulfil the purpose.	Information process in the construction companies were infected by partial or purely non-value adding activities. This problem observed in collecting data, communication, decision making, and sharing information.
Matias and Cachadinha [18]	To identify the causes of delays and material losses in the Portuguese Construction sector by analysing three main phases in the Construction process: the contract phase (CP), the planning phase (PP) and the production phase (PrP). It also intended to assess how to improve those areas of difficulties using LC solutions.	It was also concluded that LC solutions indicate improvement potential for the waste and delay sources obtained. Specific LC solutions are suggested to the problems of the Portuguese Construction's reality identified in the survey study, which have the potential to minimize and, in some cases, eliminate the causes of the problems found.
Nahmens and Mullens [19]	While providing an overview of Lean principles, the paper focused on two fundamental Lean concepts, standardization and continuous flow.	The Lean Production principles were successfully applied, yielding a 47% increase in productivity and a 25% reduction in lead time. This study also found employee involvement and the supplier relationship as key factors for successful Lean implementation.

3. Towards Effective Lean Practices in the Use and Maintenance Phase

3.1. Characterization of a BMMP

Firstly, a baseline framework must be provided which permits us to establish a forecasted application. So, its main focus will be on the relationships between different actors inside the Use and Maintenance flow. Similarly, the implementation of what can be called a Building Maintenance Management Process (BMMP) usually involves people with different functions, methods and activities and makes use of a computer program to support and coordinate. The associated management activity is normally performed by a wide range of companies, working in this particular market. They provide services to 'Customers' (building owners) which in turn need to satisfy certain requirements concerning their properties. There are many cases in which this interaction is integrated, i.e., the asset owner holds a department attached to Maintenance in its internal operating structure.

[1] The main objectives of the methods, techniques and tools of TPS were to provide value to customers in a continuous flow production, improving the performance and eliminating waste and weaknesses from the process. Taiichi Ohno, one of the creators of TPS, has defined the absolute elimination of waste as its fundamental feature, based in two pillars of sustainability: Just-In-Time (JIT) and Jidoka (Automation).

Table 2 - Some features of the Lean Thinking tools oriented to Maintenance Services ([20])

Brief description of used tools	Targets
Value Flow Mapping Considers Maintenance activities with value flow mapping and details all necessary activities.	Provides signs for proposed improvements to be implemented.
Autonomous Maintenance It focuses on the ability of workers, in regard to identifying and correcting construction pathologies.	Recurrent training - to consider as able to locate and identify the type of manifested pathology.
Database Obtains a historical of the processes development.	Digital database – the administrative activities of maintenance become more dynamic and the whole building is interconnected to a single system; Formulate a catalogue of pathologies of the constructions.
Kanban[2] As a card or label. Two types: of request and of production order	In addition to the usual practices, Kanban can be adapted to the location and description of the pathology targeted of maintenance actions.
Andon[3] It's not limited only to a problems indicator but may be used as an activities manager.	Generate opportunities for Continuous Improvement[4] (CI); It's a tool to indicate to a technician the description of an identified pathology so that he can more accurately define the parts and tools most appropriate for the Work Orders (WO).
Work cells The sectorization of maintenance areas can be advantageous.	Can be located in activity centres, where the distances from the cell to the point of incidence of pathologies are minimized.
Supermarkets Are responsible for the storage of material needed to perform maintenance activities that require spare elements.	Supplying is made according the necessity of the cells, in result of the analysis of the Kanban cards existing in each group of items of the supermarket.
Kaizen Plans Processes in which schedules are conducted and the improvements are stated.	To be deployed in a future situation, since the Lean Thinking[5] methodology is based on the CI of the activities.

In any case, the company or the department can coordinate other entities such as 'Suppliers', 'External Partners' as well as integrating a 'Storeroom' for materials supply. The Maintenance function is then theoretically implemented through an 'Organized Management System', based on fundamental concepts ('Management Items') and involving fundamental 'Maintenance Management Indicators'. To support the entire process, these features are integrated, for instance, in a centralized Computer Maintenance Management System (CMMS) - Figure 2. Notice that, similar to the Lean Maintenance, also in the BMM, the use of informatics applications (as a CMMS) can be seen like a Lean practice.

3.2. Recognized Waste in a BMMP

As is common in other cycles of Construction, the existence of waste is verifiable in the use phase of buildings. The whole understanding of the research question does not dispense a brief analysis of this particular aspect. Following, several problems with different dimension and origin are stated, usually resulting in waste:

[2] Kanban - It is a system using cards or labels to indicate the progress of production flows in manufacturing companies in series, allowing a comprehensive control of production with information about what to produce, when and the quantities.

[3] Andon - It is a warning system for the management or maintenance sectors or to other workers, concerning to a process problem or of quality. The centrepiece is a board that incorporates warning lights to indicate the workplace with that problem.

[4] Continuous Improvement (Kaizen) - directed towards the flow creation of material and information, depending on customer needs. The main objectives are to create value and waste elimination

[5] The second book published by Womack and Jones [21], presented the five principles of Lean Thinking: i) create value, or specify the value of the product; ii) define or identify the value chain; iii) optimize the flow, with a continuous and uninterrupted flow; iv) system "pull", which allows the customer to "pull the product"; v) pursue perfection.

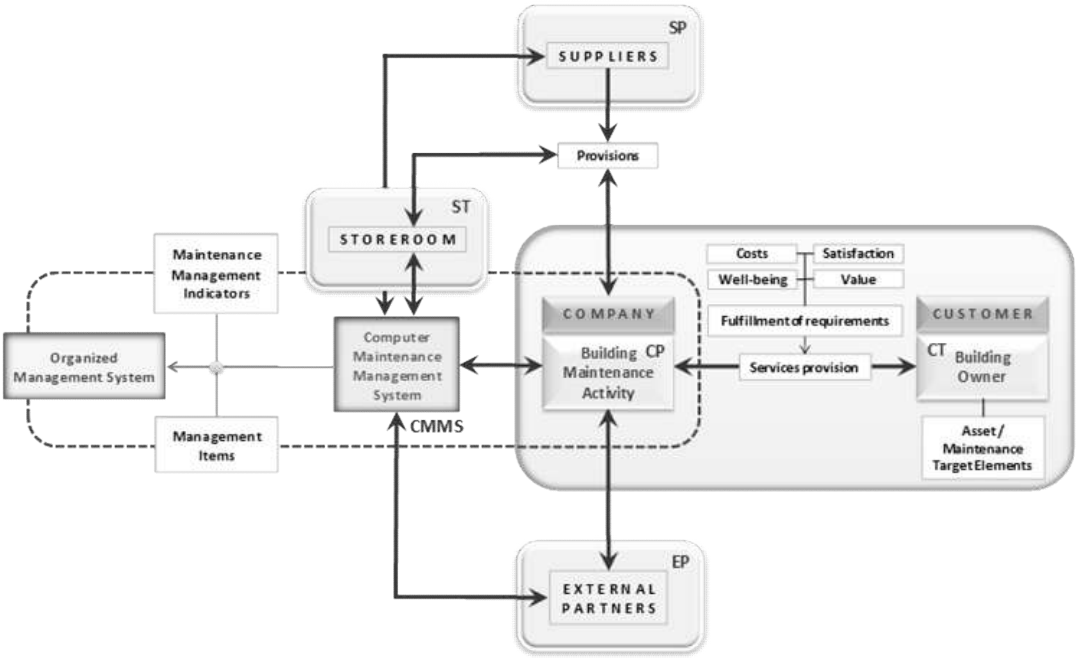

Figure 2 - Scheme representing a common practice of interactions in a BMMP

- Non-fulfilment of any basic maintenance procedures for buildings, even if with the obligation to comply with a small maintenance plan prepared after the completion of construction and before starting its use. This situation originates mainly large economic waste over the lifetime of buildings and consequently poor living conditions of users and rapid loss of the asset value;
- In cases of an applied maintenance process similar to that shown in Figure 2, even if characterized as having some basic organization, several structural inconsistencies of maintenance enforcement can persist, leading to much economic and financial waste. Generally, it results from an inefficient or unsuitable management of human resources, materials, energy and by lack of continuous improvements in its structural organization;
- Non-use of human potential: insufficient training is common;
- Delays leading to loss of time by the customers: mainly due to frequent slowness in bureaucratic procedures;
- Inadequate maintenance strategies: particularly those framing the constructive elements;
- Unnecessary work (oversized maintenance activities) or underestimated work (undersized maintenance activities).

Furthermore, additional and important viewpoints may also to be considered, principally collected from some Lean Maintenance considerations [22], and reflected as adaptable to the Building Maintenance case:

- Additional waste cases occurring in the maintenance work flow. For instance: job delays, waiting for materials, instructions, equipment, information, repairing of (constructive) elements which could be replaced;
- Losses in some procedures and techniques;
- Emergency maintenance and unplanned WO's;
- Lack of interfacing to other systems and often the non-existence of compliance requirements manuals.

3.3. Baselines for the Integration of Lean Principles

Mainly attentive to the organization of a generic BMMP as well as to the waste's main causes, the conceptual integration of Lean principles into the Building Maintenance phase can be proposed, sustained on different outlooks extracted from the literature review and considered relevance in this context. With the exercise accomplished in Table 3, it seems unavoidable to introduce and associate a new theoretical conception, which has been decided to be simply called 'Lean Building Maintenance' (LBM).

While it is intended to become an original contribution to reduce or eliminate waste, this proposal will surely attract greater attention to the agility of procedures in the BMM, above all, through a basic incidence between the different players and the system.

Basically, the LBM exercise is comprised of the base lines of a theoretical model which aims to stimulate further discussion and which, obviously, will need to be tested in practice, for example through a more incisive case study. Our research efforts will be likewise directed in this way.

3.3.1. Application Example

Taking into account some interesting aspects of the TPS (Table 3), a concrete example can be presented. For instance, it is conceivable to introduce good performances in certain procedures, such as in the following cases.

The first one is by creating an information and material flow which is dependent on the 'Customer' needs (essentially at the level of the Target Elements of Maintenance). In this situation are involved aspects of the CI (or Kaizen). Has to be drawn attention that the CMMS or the Information System used have, themselves, to be well structured and organized and remain allied to a ceaseless improvement of human performance. The second example involves aspects of the JIT and focuses on the movement of materials and workforce that occurs in the strict measure of the stipulated timings for the maintenance interventions.

Both cases have its incidence in the streams and interactions established as CMMS→EP→CP→CT and CMMS→ST/SP→CP→CT (Figure 3).

Table 3 - LBM: a proposal to integrate different Lean principles on a BMMP

Lean Principles (from the Bibliography)		Brief Description of Interesting Aspects	Purposes	BMMP Streams: Incidence and Interactions (*)
TPS [21,23,24,25]	JIT	The material handling occurs as they are needed.	To have the right product, at the right time, in the right quantities.	CMMS → ST/SP → CP → CT
	Automation	The human intelligence transferred to the machines: introducing automated techniques to monitor the elements condition - detected up to a certain level.	Triggers an automatic alarm (WO) for maintenance requirements; Efficiency and speed in the procedures.	CT → CP → CMMS; CMMS → ST/SP/EP → CP → CT
	CI	Directed towards the flow creation of material and information, depending on customer needs.	Create value; Better utilization of human capabilities; Better information in the process.	CMMS → ST/SP/EP → CP → CT; CP → ST/SP/EP → CMMS
		Unceasing improvement of human performance.		
Lean Production [24,26]		Meetings with all stakeholders in the value chain (companies, departments, teams), assisted by technicians with "Lean functions" to regularly carry out the analysis of the current situation and discuss improvement measures.	Global mechanism of revising results: start the whole cycle using the experience gained and implementing CI.	CMMS ↔ ST/SP/EP ↔ CP ↔ CT; CMMS → ST/SP/EP → CP → CT → CP → ST/SP/EP → CMMS
Lean Maintenance [27]		Performs some principal analyses: root causes failures, maintenance procedure effectiveness, PM.	Reduction and/or elimination of waste associated with labour, materials, procedures and techniques.	CP → CMMS
		Condition monitoring results.	It intends to achieve a cost reduction and a productivity improvement.	CT → CP → CMMS
Lean Thinking [21,24,26,28]	Supply Chain Management	Involves all organizations which are engaged in the manufacture or in the provision of services.	Through each one the value is created and transferred to the final customer (diffusing of Lean Thinking by all parts); Optimize the flow, having a continuous flow, uninterrupted; Lean operations, leading to the reveal of problems and corrected them; Close proximity to the customer and to the suppliers; Pursue the perfection.	CMMS ↔ ST/SP/EP ↔ CP ↔ CT
	The Customer Service	The reason why whole chain is coordinated and creates value.		
Lean Construction		Increase the transparency of internal processes.	Visible to all individuals - control and error detection easier - information closer to all actors.	CMMS ↔ ST/SP/EP ↔ CP ↔ CT
		Use the knowledge and experience of performing tasks.	Introduce CI in the process.	CMMS ↔ CP
		Benchmarking.	Learning with leading companies, which are followed by their good examples and good practices.	… ↔ CP ↔ … … ↔ CT ↔ …
Lean Management [29,30]		Optimize the changing means and the conditions of execution; Programming and management of priorities.	Improving customer services; Enhance of the tasks versatility; Eliminate low-value activities in the chain; Reduce costs of carrying out products/services; Increase the operational flexibility and time reaction.	CMMS ↔ CP → CT
Lean Green Construction[6]		An operating performance compatible with certain expectations.	Maximize the operational performance of buildings.	CMMS ↔ CP ↔ CT
		Concern with the large consumption of natural resources such as energy and water.	Energy efficiency and Environmental Sustainability.	
Lean Buildings[7]		Preference by natural sources of energy and by gains and natural dissipation of energy.		

(*) → One direction; ↔ Both directions

[6] It is a proposal to integrate models of LC and Lean Green Building to the Construction sector. [31]

[7] The concept of Lean Buildings tries to cater for the principles of Sustainable Construction. It harmonizes with data sources of surrounding climate and explores the natural dissipation of energy. Thus, providing visual and thermal comfort to residents and reducing energy needs. These kinds of buildings are based on traditional architectural practices on energy-conscious. [32]

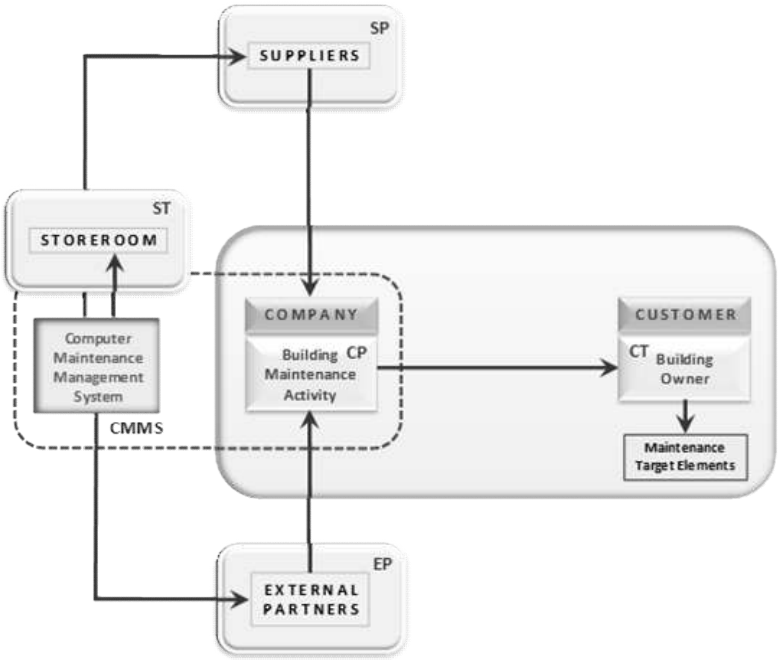

Figure 3 - Illustration of the stream incidence and of interaction in the BMMP based in the CI and JIT features

4. Discussion

The Lean thought highlights the identification and elimination of waste while maximizing value over a work process. The intended use of Lean in the BMM can include several opportunities unexploited so far. Being a current topic of great importance, this article attempts to establish a small exercise in Lean systematization of knowledge, ranging from its origins to the latest concepts identified as involving potential application into the Building Maintenance area. The performed review is still an original contribution to Lean knowledge applicable to the BMM and provides another valuable resource for researchers in this area, influencing as well the enlargement of debate boundaries within the context of the Construction sector.

The research implications are mainly directed to the requirement of re-examining and improving the utilization of management practices in the Building Maintenance phase, fundamentally with the concern of eliminating common waste. Whereupon, the utilization of Lean tools can represent many challenges for current practices in the BMM. Some complexities involved in the implementation of its procedures are usually related to the inadequacy of traditional management systems. And, however, there are only a few research works are known to be oriented to the identification of the potential fields of improvement.

This study has also been developed under some verifiable limitations, as for example certain dispersion in the use of several aspects of the Lean knowledge and some lack of literature covering the Building Maintenance stage. Moreover, the embryonic stage of our work has not, as yet, allows us to answer other more incisive questions - the research is largely limited to a

literature review, which lacks validation from extensive empirical evidence. Nevertheless, it is believed that this approach can still represent a starting point with an aim to better achieve sustainable management actions.

Then, the afforded view by a presentation framework, transverse to several ideas, has wished to facilitate the understanding of some Lean principles and tools, pointing casually to some essential power lines for the integration of the Lean philosophy into eventual forthcoming studies. At the same time, it was possible to verify that within the Lean Maintenance and LC, interesting developments have emerged, whose principals can assist with the expansion of more advanced theories and applications. Following this, the principal ideas resulting from the carried-out review allowed an opportunity to advance with a proposal of inclusion of Lean's key aspects in different flows of a BMMP, whose rehearsal is proposed to be known as Lean Building Maintenance.

5. Conclusion

It is believed that Lean researchers must be stimulated not to restrict their research only to a specific construction phase but rather in accordance with an open platform including the BMM, so that expansion can also benefit of more Lean investigation. Following this, the whole analysis established on this article seems to constitute a valuable support for the knowledge utilisation around the Lean philosophy. And above all, the necessity to update either BMM software as well as the development of new tools has to be considered. An example of this can be seen in the modulation of an integrated strategies algorithm for an Information System dedicated to in-service behaviour of buildings, currently under a development perspective.

References

[1] Picchi, F. Lean Principles and the construction main flows. 8th Annual Conference of the International Group for Lean Construction. Brighton, UK, 2000.
[2] Womack, J. The Challenge of Value Stream Management. Lean Enterprise Institute Value Stream Management Conference. Lean Enterprise Institute, Dearborne, USA, 2000.
[3] Picchi, F.: "Oportunidades de aplicação do Lean Thinking na construção". Ambiente Construído, 3 (1) (2003), pp. 7-23.
[4] Koskela, L.: "Application of the new production philosophy to construction", Technical Report No.72 (1992), Standford University: Center for Integrated Facility Engineering.
[5] G. Ballard. The Last Planner System of production control. Thesis for the degree of doctor of philosophy. School of Civil Engineering, University of Birmingham, 2000.
[6] A. Venâncio. Integração de Lean Production e Clean Production na Construção. Master's Dissertation in Civil Engineering, Instituto Superior Técnico, Lisbon, 2010.
[7] Sousa, H., Martins, J., Monteiro, A. Lean Construction. Projecto SIGABIM. Department of Civil Engineering, Faculty of Engineering of University of Porto, 2011. http://paginas.fe.up.pt/~gequaltec/w/index.php?title=Lean_Construction (17/12/2011)
[8] Sousa, H., Martins, J., Monteiro, A. Last Planner System. Projecto SIGABIM. Department of Civil Engineering, Faculty of Engineering of University of Porto, 2011. http://paginas.fe.up.pt/~gequaltec/w/index.php?title=Last_Planner_System (17/12/2011)
[9] Lee, G.; Sacks, R.; Eastman, C.M.: "Specifying parametric building object behavior (BOB) for a building information modeling system". Automation in Construction, 15(6) (2006), pp. 758-776. doi:10.1016/j.autcon.2005.09.009.

[10] Sousa, H., Martins, J., Monteiro, A. BIM. Projecto SIGABIM. Department of Civil Engineering, Faculty of Engineering of University of Porto, 2011. http://paginas.fe.up.pt/~gequaltec/w/index.php?title=BIM (17/12/2011)
[11] A. Monteiro. Avaliação da aplicabilidade do modelo IFC no licenciamento automático de projectos de redes de distribuição predial de água. Dissertation submitted for partial satisfaction of the requirements of the degree of Master Civil Engineering. Faculty of Engineering of University of Porto, 2010.
[12] Sacks, R.; Koskela, L.; Dave, B.; Owen, R.: "Interaction of Lean and Building Information Modeling in construction". Journal of Construction Engineering and Management, 136(9) (2010), pp. 968–980. doi: 10.1061/(ASCE)CO.1943-7862.0000203.
[13] AlSehaimi, A., Tzortzopoulos, P., Koskela, L. Last Planner System: experiences from pilot implementation in the Middle East. 17th Annual Conference of the International Group for Lean Construction. Taipei, Taiwan, 2009.
[14] W. Gonçalves. Utilização de técnicas Lean e Just in Time na gestão de empreendimentos e obras. Master's Dissertation in Civil Engineering, Instituto Superior Técnico, Lisbon, 2009.
[15] G. Jacobs. Review of Lean Construction conference proceedings and relationship to the Toyota Production System framework. Submitted for the partial fulfilment of the requirements for the degree of doctor of philosophy. Colorado State University, Fort Collins, Colorado, 2010.
[16] Seppanen, O.; Ballard, G.; Pesonen, S.: "The combination of Last Planner System and Location-Based Management System". Lean Construction Journal, (2010), pp. 43-54. http://www.academia.edu/2800435/The_Combination_of_Last_Planner_System_and_Location-Based_Management_System (04/09/2013)
[17] A. Golyani, H. Hon. Information handling in construction projects - a study in Swedish Construction companies. Master's Thesis in the MSc Design and Construction Project Management. Chalmers University of Technology, Gothenburg, 2010.
[18] Matias, J., Cachadinha, N. Evaluating the potential benefits and challenges of Lean Construction adoption in the Portuguese Construction Industry: a survey study. 18th Annual Conference of the International Group for Lean Construction. Haifa, Israel, 2010.
[19] Nahmens, I.; Mullens, M.: "Lean homebuilding: lessons learned from a precast concrete panelizer". Journal of Architectural Engineering, 17 (2011), Special Issue: Residential Construction, pp. 155–161. doi: 10.1061/(ASCE)AE.1943-5568.0000037.
[20] L. Salermo. Aplicação de ferramentas da Mentalidade Enxuta e da Manutenção Autónoma aos serviços de manutenção dos sistemas prediais de água: estudo de caso: Hospital das Clinicas da UNICAMP. Master's Dissertation in Civil Engineering. State University of Campinas, São Paulo, 2005.
[21] J. Womack, D. Jones. Lean Thinking: banish waste and create wealth in your corporation (2nd ed.). New York: Free Press, 2003.
[22] Bagadia, K. Lean Maintenance: how to go Lean to maximize cost savings, 2009. http://www.thetfmshow.com/Assets/Content/doc/R105%20-%20LEAN%20Maintenance%20How.pdf (01/07/2011)
[23] Pinto, J. Lean Thinking – glossário de termos e acrónimos. (2008) http://www.leanthinkingcommunity.org/livros_recursos.html (25/11/2009)
[24] Pinto, J. Lean Thinking – criar valor eliminando desperdício. (2009) http://www.leanthinkingcommunity.org/livros_recursos/Joao%20Pinto%20Introducao%20ao%20Lean%20Thinking.pdf (02/10/2011)
[25] T. Ohno. Toyota Production System. Cambridge: Productivity Press, 1988.
[26] J. Womack, D. Jones, D. Roos. The machine that changed the World: the story of Lean Production. New York: Free Press, 1990.
[27] Smith, R. What is Lean Maintenance. (2004) http://www.mt-online.com/component/content/article/116-october2004/912-what-is-lean-maintenance.html. (30/09/2011)
[28] CLT. A criação de valor através da eliminação do desperdício. (2008) http://www.leanthinkingcommunity.org/ referred by [24]
[29] Online24 Lean Management http://www.online24.pt/lean-management/ (30/09/2011)
[30] Iberogestão. Lean Management – Melhoria da eficiência operacional (2007) www.iberogestao.pt/noticias/folheto_a3_lean_200706.pdf (30/09/2011)
[31] Junior, A., Filho, J. O Conceito Lean Green de construção: proposta de integração dos modelos Lean Construction e Green Building, aplicado à indústria da construção civil,

subsetor edificações. XXIV Encontro Nacional de Engenharia de Produção. Florianópolis, Brazil, 2004.
[32] Voss, K., Reinhart, C., Löhnert, G.,Wagner, A. Towards Lean Buildings – examples and experience from a German demonstration program for energy efficiency and solar energy use in commercial buildings. EuroSun 2000, 3rd ISES-Europe Solar Congress. Copenhagen, Denmark, 2000.

3.4. Main functions for building maintenance management: an outline application

Contribution:

Falorca, J.,

Main functions for building maintenance management: an outline application, *International Journal of Building Pathology and Adaptation*, 2019,

DOI: https://doi.org/10.1108/IJBPA-08-2018-0067.

Main functions for building maintenance management: an outline application

Jorge Furtado Falorca
Independent Researcher, Covilhã, Portugal.

Abstract

Purpose – The purpose of this paper is to present an algorithm of procedures intended for use in building maintenance management (BMM), called SIAPME.

Design/methodology/approach – With basis on a literature review, an exploratory practical exercise was carried out, drawing up the SIAPME model and comprising several organisational charts with interconnections.

Findings – This study offers an overview of an alternative set of well-founded and integrated strategies for asset management. Overall, the basic characteristics of the outlined model seem to be in agreement with various existing models.

Research limitations/implications – SIAPME's ambitious goal is to serve as a well-founded strategic basis for the development of an advanced software solution. However, it still lacks empirical validation, which could be a lengthy process.

Practical implications – This research can provide a valuable input for a more in-depth discussion on the identification and correction of gaps for many systems currently in use. For instance, it is believed that an eventual SIAPME software solution may have potential for full compatibility with building information models, particularly focusing on the life cycle phase of utilisation, operation and building maintenance.

Originality/value – Through SIAPME procedures, a building manager will be allowed to have a very broad perspective of its functions, covering nearly all the fundamental aspects for efficient and integrated maintenance, with optimal control of all players in the process. As a concept idea and by introducing emerging and technological issues, the model can be advantageous for BMM.

Keywords: Building maintenance, ICTs, Systems, Algorithm of procedures, Computer applications, BIM.

1. Introduction

This paper addresses the issue of building maintenance management (BMM) as one of the most promising activities in the field of contemporary civil engineering. It presents an

algorithm of procedures for BMM (generically called SIAPME) and intends to be a further contribution towards optimising management practices in a building maintenance (BM) framework.

Buildings have been amongst the most valuable assets of any nation in the sense that they provide people with shelter and facilities for work and leisure (Vijverberg, 2002; Lam et al., 2010; Wang, 2017). It is known that the specific perspective of BM still does not receive the attention it should. Indeed, according Silva and Brito (2019), for decades the maintenance of buildings was seen more in a reactive perspective, based on subjective criteria. However, more recently, maintenance has been considered to play a greater role in the entire lifespan of buildings (Mydin, 2017). In recent European Standards (BS EN 13306, 2017) maintenance is defined as the "combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function". To Akasah et al. (2009), maintenance is a continuous operation to keep buildings, infrastructures and equipment in the best form for regular utilisation, although BM is regarded by Yin Lee and Scott (2008) as a major activity in the construction industry, essential whether the building is large or small, simple or complex.

Until the 2008/2009 economic crisis, the construction of new buildings, particularly for housing, had strongly marked this sector in some southern European countries, such as Portugal, reaching higher volumes than the European average (Vilhena, 2011). While this situation persisted, little attention was directed to the rehabilitation and maintenance of buildings and a lack of consolidated practices in the maintenance of built parks was common (Silva, 2010). Irrespective of this, BM is normally regarded as a core activity, in particular because of the volume and variety of building stock, often of advanced age. Notice that BM has already accounted for over half of the total output of the building industry (Wordsworth, 2001). Despite a slowdown during the recession, signs are showing that the activity is again experiencing some confidence and reinvigoration. For instance, in the UK the maintenance expenditure as a percentage of gross domestic product, is at its highest level since 2009 (RICS, 2019). Although BM activity may have, in the short or medium term, a significant strengthening of its scale of implementation, it seems that it is already facing with even demanding customers and situations, seeking effective services of higher quality and speed, without involving significant increases in costs. The challenges of effectiveness of maintenance strategies have already been analysed by Yin Lee and Scott (2009) and some of the other biggest BM challenges are also indicated by Christiansen (2018).

It is quite common for many public authorities or public–private and private companies to opt for the use of external contracted services to ensure the effective functioning of their assets. On the other hand, there are entities embracing BMM, opting to invest in their own tools and methods in order to optimise operations. Both situations can require a great capacity for adaptation, diligence and innovation from the stakeholders involved. The use of advanced

means to facilitate these functions is already very common. Molinari et al. (2002) addressed the issue of systems of information for the maintenance management (MM) of buildings concluding that they are essential to support the control of technical performances and economic values of buildings. Also, a wide range of options inside the field of information and communication technologies (ICTs) currently exist, specifically directed to support BMM. According Ismail and Kasim (2013), the ICTs developments give great potential to efficiently process and communicate a large amount of information during BM. The market possibilities of software or related applications are currently broad ranging, with different approaches in terms of integration, functions and degrees of success (Falorca et al., 2011). Technology is accessible and is being used, enabling the building-up of profiles of maintenance (Wood, 2005). The technology development in BMM has been quickly upgraded and device advances have allowed easier integration opportunities (Zakiyudin et al., 2016).

In this context, the emergence of contributions aimed at improving real estate asset management methods, mainly through careful planning of processes and activities, is essential. One way forward can be through the development of more scientifically well-founded research and guidelines. Recently, a study has been carried out, to outline a management information system model, with the aim of being realised in a computer-readable form and thus viewed as a functional performance facilitator of any organisation, regardless of its size and the patrimonial portfolio concerned. This model has a set of guiding principles and sustainable strategies and it is thought to be more promising if it embraces an innovative design base, more comprehensive and integrative of all information. The outlined application was generically entitled “Information System for Automatisation of Procedures in the Building Maintenance Management” – initials in Portuguese: SIAPME. This paper presents the main ideas underlying its achievement. Thus, Chapter 2 comprises a literature review made on aspects of models and systems of MM in the scope of the buildings, as well as some related developments in the background of ICTs.

The methodological approach is presented in Chapter 3 and a view of the generic features of SIAPME is given in Chapter 4. A comparative critical analysis and the SIAPME’s experimental computerised form are both briefly addressed in Chapters 5 and 6, respectively. The last paragraph contains the generic conclusions of the study.

2. Literature review

2.1 Models and systems of maintenance management – considerations in the scope of buildings

Entities responsible for BMM should establish the maintenance policy and strategy, define the processes, activities and resources to meet the user’s expectations and ensure the maintenance service quality provided. To attain this goal, the systems or models used generally have different approaches, depending on the circumstances. Bibliographic research

has allowed a set of publications to be found such as standards, guidelines, academic studies and others some focusing on different uses of constructions, including housing, schools, universities, hospitals, etc.

For instance, regarding standards, the Portuguese guideline NP 4483 (2009) has its focus on the implementation of the maintenance management system (MMS), although directed more at buildings, BS 8210 (2012) gives guidance on the MM of facilities. EN 15331 (2011) outlines the criteria for design, management and control of maintenance services for buildings and ISO 55001 (2014) specifies the requirements for an asset management system within the context of an organisation.

Related to housing, a framework of guidelines from the Department of Housing and Public Works in the State of Queensland in Australia (QDHPW, 2018) has also been reviewed. Hunt (2016) presented a comprehensive facility operation and maintenance (O&M) manual and Dixneuf et al. (2014) drew an exhaustive inventory of the operations to be implemented in BM. Raposo et al. (2011, 2012) presented a critical analysis on some international guidance documents as well as an insight to several international practices implemented for BMM systems, while Natário (2016) carried out an examination of the real state of a large public institution in the social sector and developed a tool to support MM of the building stock.

More specifically, in relation to management models for public social housing stocks, situations concerning the UK and the Netherlands can be given as important examples. Cooper and Jones (2008) studied the maintenance practices of the English extensive social housing stock, where according to the government (MHCLG, 2018), the social rented sector accounted for 17 per cent of households. In a doctoral thesis, Cooper (2015) explored the viability of integrating the sustainability agenda with social housing maintenance decision making, resulting in the presentation of a performance-based sustainable model. Sagoo (2014) identified the critical factors that drive the decision-making process to formulate responsive housing maintenance strategies and to further develop a decision support model to improve customer service delivery of social housing provision. According to Housing Europe (2010), the Netherlands is also the country with the largest share of social housing in the European Union, accounting for about 32 per cent of the total housing stock and covering 2.3m rental homes owned by social housing associations (GN, n.d.). In this context, Straub (2002) considered that a MMS fulfils an important role in the support of technical management processes and it must be capable of being introduced as a policy instrument. In turn, Vijverberg (2004) addressed a strategic housing stock policy and MM practices, and Goedknegt and Ravesteijn (2016) presented an explorative study focusing on the upgrading maintenance processes through improving both the coordination mechanisms and the use of Information Systems (IS). In Portugal, GEBALIS is the company responsible for the municipal housing in Lisbon, covering the integrated management of a portfolio of around 23,750 residential units in 2017 (GEBALIS, 2017, 2018).

Still on the housing theme, Muczyński (2016) has presented a comprehensive model of municipal housing stock management in the context of conditions in Poland. To address the decision making on the preparation of a multiyear action plan pertaining to the maintenance and upgrading of properties, Taillandier et al. (2014) also developed and tested an interactive decision support method to support the housing stock managers (called Real Estate Management INteractive Decision).

With respect to school buildings, for example, the Department for Education in England have launched the manual "Good estate management for schools", with the policies, processes and documents that schools and others should consider when managing their estates (Gov.UK, 2018). Along the same line, the Victoria State Government of Australia also provides the "School policy and advisory guide" with governance and operational policies for Victorian government schools (SGV, n.d.). It includes a facilities and infrastructure policy allowing advice and support on areas such as property and asset management and ICT supply and maintenance. In Portugal, the Parque Escolar is responsible, for the conservation, maintenance and operational support of many state schools (about 167 schools in 2016 – PE, n.d.). The objectives of this model are, above all, planning conservation and maintenance intervention and to reduce the probability of damage, failure or degradation of the assets. In the same way, a methodology for measuring and evaluating the performance of building stock was developed by Silva (2010). This has a built-in analysis tool that integrates key performance indicators (KPIs) on technical, economic and organisational aspects and the MMS was tested in a sample of five primary schools in Lisbon.

Regarding the management of university real estate, an important piece of work on the management of the campus of the University of Savoie was developed by Bonetto and Sauce (2005) – as referred to by Silva (2010). Likewise, according Raposo et al. (2012), this work represents a strong contribution to the identification and mapping of the processes required for the management of built heritage. In France, buildings allocated to higher education and research account for almost 40 per cent of the state's real estate assets (MENESR, 2014). To propose a pragmatic method of optimising and renewing university assets, the French government published the guide "Optimiser et rénover le patrimoine immobilier universitaire" (MENESR, 2014). It presents a concrete action plan and considers the long-term O&M of renovated buildings. Meanwhile, research by DeMedici and Senia (2015) took an Italian university as a pilot case and a system for planning and control of maintenance services was developed, with the aim of increasing the quality in management of real estate for university education. Silva and Falorca (2009) also presented a model plan for BM, called PIMEC, tested on university buildings.

With the focus on MM of healthcare buildings, other studies have also been published recently. In this case, for example, Enshassi and Shorafa (2015), Omar et al. (2016), Shohet and Nobili (2017) and Shohet and Lavy (2017) considered the use of KPIs; Galán and Gómez

(2018) carried out a general review about the MM models; Olanrewaju et al. (2018) proposed a conceptual framework of maintenance model; and Jandali and Sweis (2019) have made an assessment of factors affecting MM performance.

The assessment of building condition is also viewed as an essential activity into BMM. For some years now, this issue has been widely studied at a national and international level, with several interesting methods being developed by many institutional or legislative initiatives. In the UK, the government (Gov.UK, n.d.) has made a series of documents accessible relating to Housing Health and Safety Rating System, as well as guidance on how the decent homes standard should be implemented (DCLG, 2006). Other examples are also described in the Portuguese Method for Building Condition Assessment – initials in Portuguese: MAEC (Pedro et al., 2008) and the Dutch standards for assessment of building condition as referred to by Straub (2009). In addition, a method known as "Performance-based Diagnosis Applied to the Rehabilitation of Buildings" has been outlined by Lanzinha and Freitas (2009). Chang and Tsai (2013) introduced a knowledge-based navigation system for building health diagnosis and most recently, Bortolini and Forcada (2018) presented a building inspection system for evaluating the technical performance of existing buildings.

2.2 The background of ICTs

2.2.1 Technological trends to support BMM

An analysis of the scientific literature and of the existing practices has led Taillandier et al. (2011) to recognise two main approaches to performing maintenance plans – the automated computer-aided approach and the operational approach. In the opinion of Silva and Brito (2019), the effective planning of maintenance strategies needs the emergence of accurate tools to aid stakeholders' decisions about when and how to intervene. In fact, a broad analysis of the progress achieved in recent decades in the use of computers and development of specific software for MM, has led to the conclusion that the introduction of computers and custom software substantially improves the capacity of physical asset managers on collecting, monitoring and evaluating data, as well as in the strategic decision making relative to the level of service required.

As shown by a timeline for technology development in BM, as laid out by Zakiyudin et al. (2016), computers started to assist in maintenance in the 1970s and over the next decade, maintenance software was developed. That was when, stemming from the management information systems (MIS), the first maintenance management information systems appeared, directed towards property management and maintenance (Cattell et al., 2004). The MIS are still under study and can be used, for instance, for real estate and property management (Amannah, 2017). Meanwhile, in the 1990s, the Computerised Maintenance Management System (CMMS) became popular and some activities covered were the financial monitoring, maintenance scheduling and buildings and asset condition surveys (Jones and Collis, 1996).

Based on available literature, Ismail and Kasim (2013) observed that ICT usage in MM are mostly in three areas of Information Technology (IT): based systems (building management systems); general software (word processors, spreadsheets, project management and AutoCAD); and databases (meters reading databases, maintenance request details databases and others). Numerous MMS are currently available utilising IT-based systems to replace former systems which used conventional methods. The CMMS application has arisen from the development of IT-based systems, at present being widely used in MM processes for building facilities. However, at this level there are other applications such as Computer-Aided Facilities Management (CAFM), Integrated Workplace Management System (IWMS) and Facility Management Information System (FMIS) which can record and process data for future maintenance references (Ismail, 2014). According to Madritsch and May (2009), the CAFM provides efficient IT tools for the mapping, evaluation and controlling of facility management structures and processes while CMMS is typically used for computer systems that assist in planning, managing and analysing maintenance processes. The implementation and use of IS and ITs in the facilities management business domain have also been investigated by Ebbesen (2016). For organisations, ICTs can be powerful strategic and tactical tools and if properly applied and used, can bring substantial advantages to their competitiveness (Aziz et al., 2016a).

In a critical review of existing CAFM systems, Nelson et al. (2006) had mentioned that numerous emerging technologies would be important in the development of next-generation facilities management systems. A subset of these was discussed, such as Wireless Communication Systems, Web Services, Agent Technologies, Context-Aware Computing, Wireless Sensor Networks and Tagging Technologies. More progress had been made in the meantime and MMS are also making use of Radio Frequency Identification (RFID), Non-Destructive Testing (NDT) and sensors (Zakiyudin et al., 2016). A comparison between some of the above MM technologies (RFID, CMMS, CAFM, FMIS, IWMS and NDT) in respect to 16 functions has been carried out by Ismail and Kasim (2013). In this context, it was possible to verify that CMMS was the most comprehensive tool. Virtual reality (VR) and mobile augmented reality (AR) are also technologies showing growth (Zakiyudin et al., 2016). For example, Sampaio (2016) described a VR model to assist in BM and, in turn, Woodward and Kuula (2015) presented the implementation of a mobile AR system for BM workers.

2.2.2 Computer applications and software

Over the last few years, many software tools have been developed, many of which are of a commercial nature, and others for private use or resulting from research projects, etc. Since there is such a wide range of examples, a more in-depth analysis would be too lengthy for presentation here. But in literature, there are some relevant approaches. For instance, Neelamkavil (2009) provided a synopsis of several computer-based tools that were available in the market, mostly targeted at facility MM. In addition, Falorca et al. (2011), made a study

referring to certain programmes, reporting on the importance of their generic characteristics. In a slightly different context, Ismail and Kasim (2013) described the functional disciplines of various latest technologies by type of system and functionality.

Making an internet search, several websites can be found, describing numerous software options available, each with its own peculiarities. Through a brief examination of the main characteristics of some, a perception is made that they can provide value essentially in a range of areas such as MM, asset management, real estate portfolio management, etc. Yet, it seems that the prospects for the development behind commercial software are very much based on today's business competition, allowing an adaptation to each sector of activity according to a philosophy of available and flexible "modules".

2.2.3 Towards building information models (BIM) growing involvement

In recent decades, the construction sector has shown a growing interest in the use of BIM (synonyms: building construction information model, building information modelling), since during the planning, design and construction of new buildings, it brings benefits and resource savings (Volk et al., 2014). The BIM term was created to distinguish between a new generation of IT and computer-aided design for buildings and the traditional computer-aided drafting and design (Lee et al., 2006). Through a quick analysis of a large volume of literature on this topic, it is possible to find varying definitions for BIM.

However, in a brief overview, BIM is defined by the international standards as "a shared digital representation of a built object […] to form a reliable basis for decisions" (ISO 29481-1, 2016). Eastman et al. (2011) referred to BIM as a new approach and as an activity that can eventually involve wide process changes in design, construction and facility management. Also, Sampaio (2018) referred to BIM as "the process of generating, storing, managing, exchanging, and sharing building information".

The question of how to manage buildings efficiently and effectively has always been a major challenge. With the emergence of BIM processes, this debate has had renewed significance due to the assumption that BIM information collected during a facility's life Q2 cycle could help to improve the management efficiency of the existing asset (Kelly et al., 2013). As a rapidly developing technology, BIM has demonstrated potential in tackling problems in all phases, including in the O&M phase (Cheng et al., 2016). Despite BIM methodology being an important reference for the construction of new buildings, according to Carbonari et al. (2018) it is, however, getting attention from owners of large building stocks, since they want to take advantage of the benefits of BIM as a coordinated system for sharing information and data. It is worth noticing that in most existing practices, facilities data is collected from the handover of paper documents and is re-entered manually in a computerised information system such as CAFM or CMMS (Teicholz, 2013).

Therefore, directed towards the main issues covered by present study (BM, MMS, facilities management, asset management and existing buildings), a bibliographic survey on the relation with BIM was conducted, highlighting relevant aspects of the current situation.

In fact, the BIM topic in facilities management has become an important subject of study recently (Aziz et al., 2016b). Several contributions have been added, investigating the value and challenges of BIM, not only in the facilities management context, but also with focus on BM and existing buildings. Some works have accomplished this, both through literature reviews (Volk et al., 2014; Ilter and Ergen, 2015; Aziz et al., 2016b; Pärn et al., 2016; Kelly et al., 2013) and through various other studies (Ahn and Cha, 2014; Barbosa et al., 2016; Sampaio et al., 2016; Alwan, 2016; Cheng et al., 2016; Bortolini et al., 2016; Cecconi et al., 2018; Carbonari et al., 2018; Matarneh et al., 2018; Mirarchi et al., 2018).

Consequently, a general analysis of available literature has that the use of BIM in the phase of O&M of buildings has associated advantages, limitations and challenges. In a case study, Bortolini et al. (2016) concluded that the integration of BMM in BIM can be a support for maintenance decisions, increasing the efficiency of the maintenance process. The literature reviewed by Kelly et al. (2013) on BIM for facility management showed that its value adding potential comes from the improvement to current manual processing of information handover as well as to the accuracy of facility management data. Matarneh et al. (2018) also asserts that although there are commercially available technologies for transferring data between BIM models and facilities management systems, the process may not be straightforward or cost effective. The lack of interoperability between software systems and a limited integrated view of multiple domains for decision support, are some of the limitations to explain why the potential of BIM in the O&M phases has not been fully utilised (Cheng et al., 2016). Thus, the necessity of best practices so that data transfer strategies are developed and documented (Matarneh et al., 2018), can be a challenge.

3. Methodological approach

The methodological approach to achieving the SIAPME algorithm had a preliminary phase of a bibliographic review on several topics considered as of essential interest. In the next stage, the knowledge assimilated from the review and personal knowledge gained from study and experience was integrated in order to build the algorithm.

To verify the reliability of the model, a comparative critical analysis with other cases was then made, as well as the identification of its strengths and weaknesses.

The approach underlying the main phases of this study is represented by a simple diagram in Figure 1.

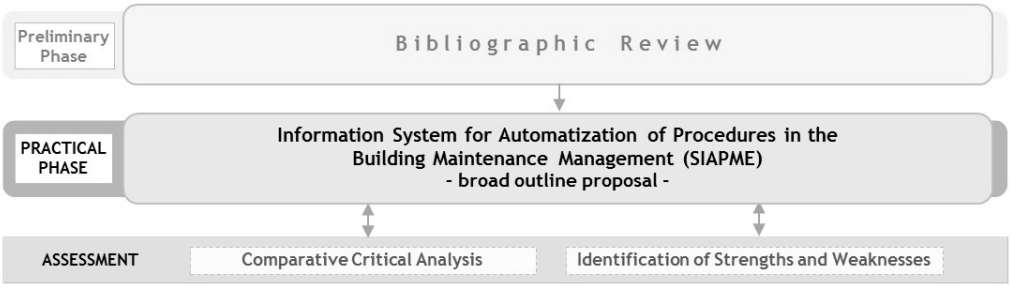

Figure 1. Overview of the methodological approach to develop the SIAPME

The main topics covered in the bibliographic review are briefly described as follow:

(1) An analysis of the general fundamentals of BMM. Works with analogous points or features identified – Yin Lee and Scott (2009), Straub (2012), Falorca et al. (2013a), Lateef and Abdul-Aziz (2015) and Mydin (2017).

(2) A bibliometric study, with the aim of creating the basis of a catalogue of bibliographic resources, to be used in conjunction with the SIAPME future computerised platform and to be made available to SIAPME users and managers. Studies can be found, some reflecting upon bibliometric analysis (Falorca et al., 2014; Santos et al., 2017), literature searches (Wing et al., 2016) and literature analysis and reviews (Au-Yong et al., 2016; Che-Ghani et al., 2016; Puķīte and Geipele, 2017; Lohmann et al., 2017; Galán and Gómez, 2018; Chong et al., 2018).

(3) An insight into cases of models and systems for MM, with origin, development and application in the field of industrial maintenance, as this can be a source area for such theory and operability of the BM. Some related and comprehensive works have been developed, like those of Sherwin (2000), Gaspar (2003) and Marquez and Gupta (2006).

(4) An analysis of models and systems covering a range of building types, as reviewed early, in Section 2.1.

(5) An approach to the lean concepts and philosophies and their applicability to BMM. The objective here was to find a theoretical way of streamlining flows, resulting in a lean interactions scheme. Higher developed researches may be identified, such as the studies made by Gonçalves (2014) and Aldairi (2017).

(6) Aspects such as comfort, energy efficiency, renewable energies and energy management. These are increasingly emerging as new challenges. Therefore, the review contained elementary insights on these topics. Worldwide, a few practice guides have been developed, such as the FMA (2012) publication, which covers aspects of sustainability, energy and water management, health and amenity issues. Also, the sustainable facilities tool (GSA, n.d.) is an important contributor, providing valuable information about sustainability.

(7) An analysis on ICTs, viewed as essential tools to support BM. More comprehensive considerations on this topic were addressed in Section 2.2.

The second phase consists of the development of a proposal for the core functions of BMM. These form the SIAPME algorithm, as is presented in this paper. The different steps were conceived through the development of many organisation charts with interconnections and individually inserted in several worksheets of MS Excel files. This kind of programme was used provisionally, because it is a facilitator in the progress and aggregate exposure of the concept, as well as to the realisation of hierarchical graphical models. Considerations on the comparative critical analysis and on the strengths and weaknesses of SIAPME are included in Section 5 and 6, respectively.

4. Main features of the SIAPME algorithm

4.1 Functional extension

In a brief description, the organisational algorithm planned for SIAPME provides a range of functions allowing interactions between four sector entities: Management of the Organisation, Real Estate (building stock), Outsourcing (Outside Staff and Services) and Interaction between the system's Users (see Figure 2).

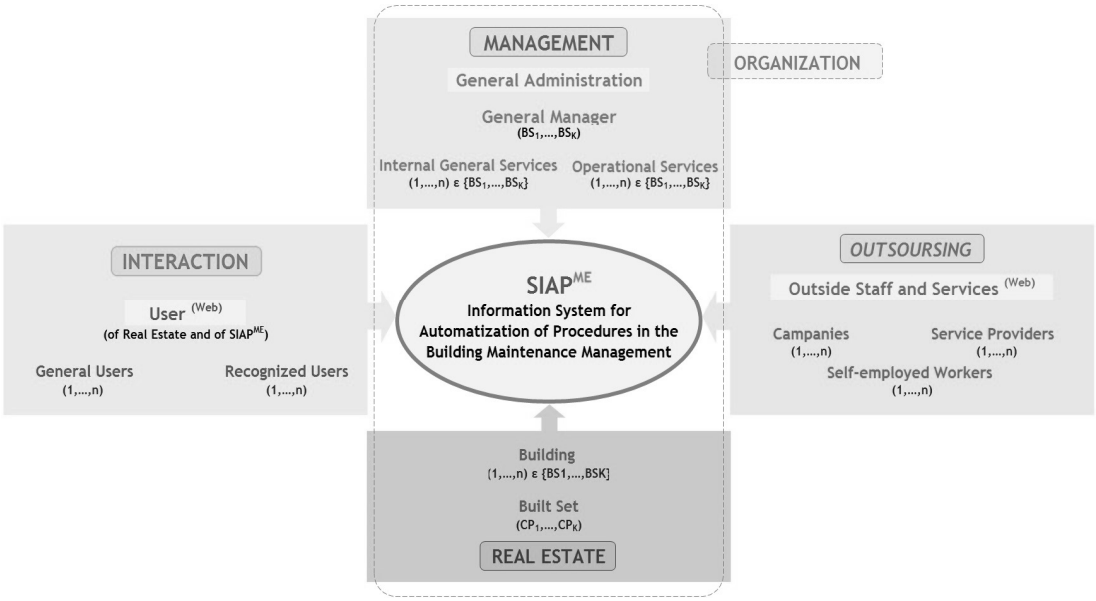

Figure 2. Schematic representation of the functional amplitude of the SIAPME algorithm

4.2 The General Manager

The General Manager (GM) will interact with the Outsourcing and all Users, through SIAPME itself.

Therefore, the GM is assigned the role of General Management, whose field of action connects to an intrinsic window (please see Figure 3). In total, there are six Main Lines which the GM must follow and try to fulfil. So, by clicking:

(1) Management Levels - refers to an informative area (worksheets) generically covering Strategic Level, Tactical Level and Operational Level;
(2) Class Management - connects to an area of verification and control of basic aspects used in the World Class Maintenance (WCM) model;
(3) Cycle of Continuous Improvement - there is a connection to an informative area intended for the constant monitoring of aspects related to Strategy, Resources, Operation, Review and Continuous Development;
(4) Benchmarking of the Organisation - an area with several steps opens, covering Requirements of the Benchmarking Process, Type of Benchmarking used and Steps of the Benchmarking Process;
(5) "Lean Building Maintenance" (LBM) - the corresponding window addresses the interactions that must exist in a general Building Maintenance Management Process (BMMP), similar to that dealt with in Falorca et al. (2013b);
(6) Sustainable Facilities - links to a peripheral field, to deal with this subject.

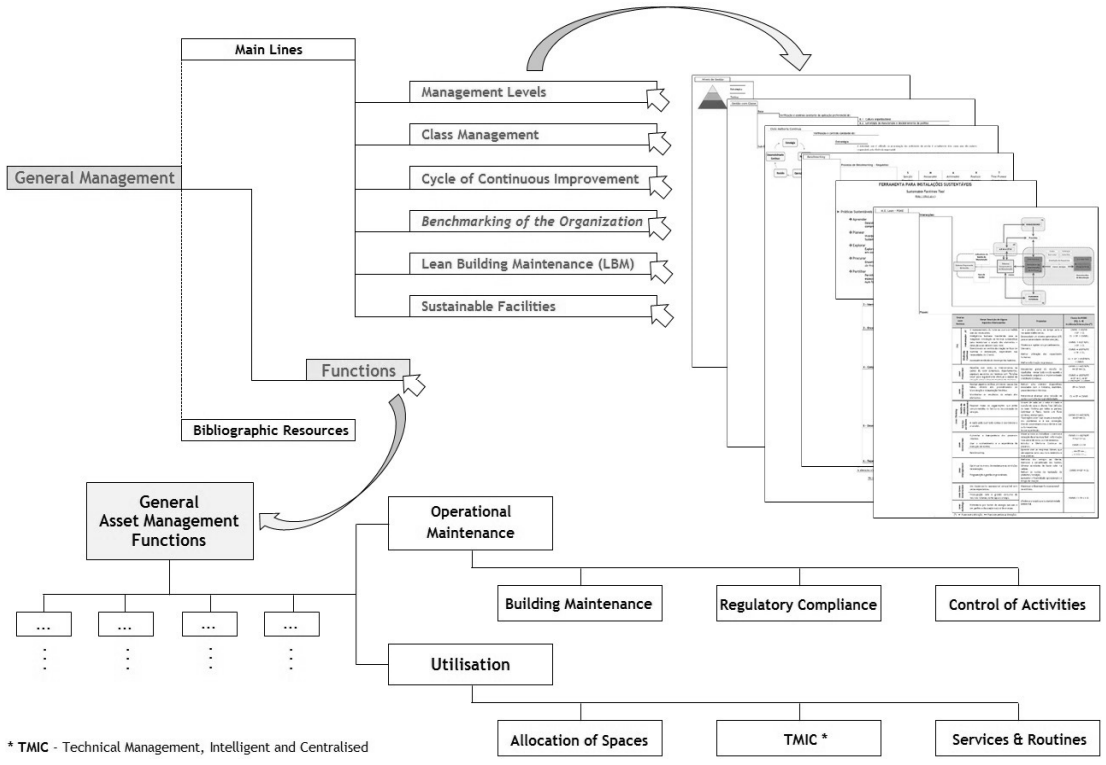

Figure 3. Schematic representation of the main lines and functions in the context of General Management

There is also a bibliographic resources option, giving full access to a catalogue. In this case, the records formed provisionally by a set of interconnected files with the extension .xls. Clicking on the Functions button, the user has access to what is considered the core of the SIAPME, entitled General Asset Management Functions (GAMF). Some of these functions are shown at the bottom of Figure 3.

4.3 The General Asset Management Functions (GAMF)

The GAMF enable users to view (with full or restricted access) those functions which are considered important for real estate management, covering virtually all the fundamental aspects of this activity. For instance, Operational Maintenance comprises the modules of:

(1) BM - embracing Strategic Maintenance Planning (SMP), Maintenance Resource Management and Economic Management of Maintenance;
(2) Regulatory Compliance - in which a Global Regulatory Compliance Assessment of the Building is scheduled annually, as well as an Update of Regulatory Maintenance Activities at SMP level and the existence of an updated file of Legislation/Standards relating to several aspects;
(3) Control of Activities - mainly on a Technical and Economic Level, for Maintenance Execution (based on a scheme of planned Work Orders) and through a Balance Sheet. As an example, Figure 4 shows a possible configuration for the level of Strategic Options in the case of mechanical equipment such as lifts and escalators (somewhat in agreement with Portuguese legislation), which in turn is part of a General Plan of Utilization Routine.

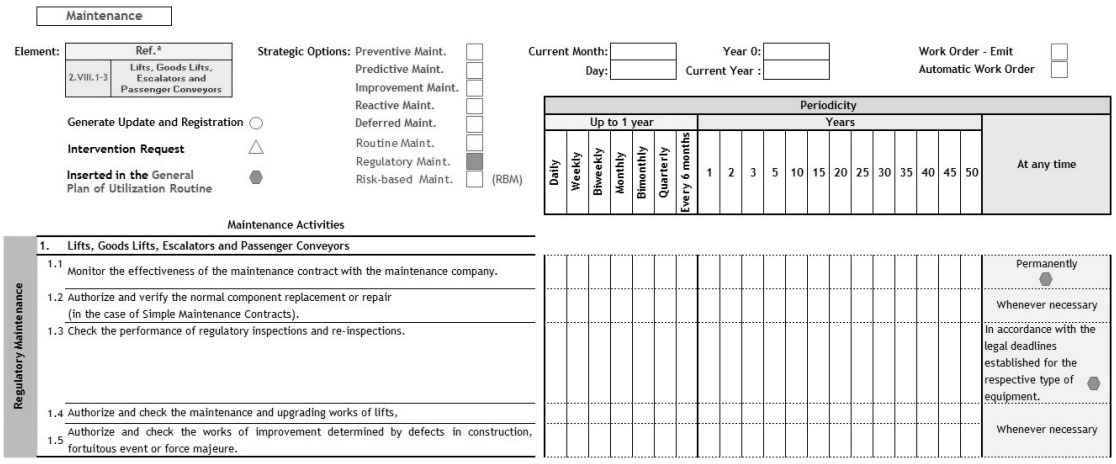

Figure 4. Operational Maintenance – configuration for Strategic Options – example of Regulatory Maintenance for mechanical equipment of ascension and transportation

Regarding the Technical Management, Intelligent and Centralised (TMIC), it is intended to completely centralize the Management of Technical Areas of operation in one building or in a building portfolio (regardless their size), connecting ten different areas, such as those indicated in Figure 5. The main objectives are to monitor, measure and optimise all existing resources to make global management more economically, technically and socially sustainable. It is further envisaged that TMIC will link to Facilities and Equipment Use Instructions, through several sub-options, including, for instance, a Connection to several simulators of Water, Energy, Energy Efficiency Performance and Energy Efficiency Manuals, Fire Safety, etc. A field is also planned to address several Services & Routines. In this

configuration, the Services option covers the field of Cleanings, supervision of Reception/Entry, Security/Access Control, etc. In addition, there is a Building Communication Channel for Users and for General Management, as well as a broad General Plan of Utilisation Routine.

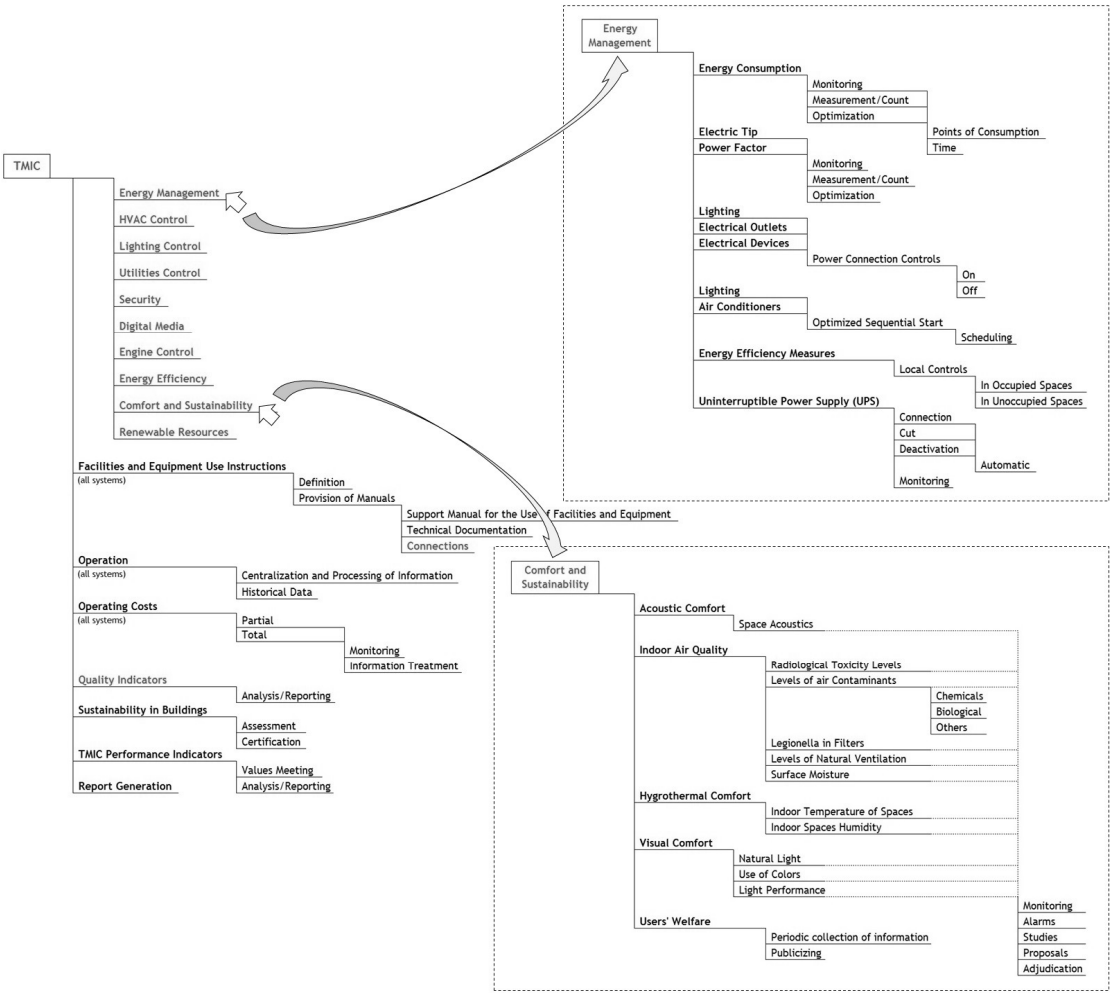

Figure 5. Schematic representation of the TMIC field configuration and example of the Energy Management and Comfort and Sustainability sub windows

4.4 Integrated information

An Integrated Information unit is also intended to be provided in this model. This will consolidate available and gathered information relating to the History of each Building Element (BE) and each Building, as well as data from other sources. The idea for this field is expressed graphically in Figure 6.

This option will have two clickable areas. If the user requires Integrated Information about a BE, it must be searched for from the available list (or selected it from other areas of the program where it is available or visible, e.g. in the building project, etc.). By selecting this, a time schedule with a set of information will appear. This timeline will then provide the current date, date of introduction of the BE on the building (or operational initial date) and

all Maintenance Actions (MA) completed, including the respective date and related data, such as Type of MA and its Description, information on the Level of Quality, Costs and if it results (or not) from an Unexpected Event. In any situation where a BE is a Replacement Case, there is another window with the same type of information. Instead, if the user requires Integrated Information about a Building, a table will appear. All MA are marked for each year, as well references to each BE, and it includes information on each of the four major groups considered in this study (BEs, Facilities & Equipment, Outside Spaces and Others). The intention is that by going over each MA, the data for each group is shown. It is further envisaged that at the bottom of the table, a column chart will show the cumulative annual number of MAs, as well the cumulative annual maintenance cost.

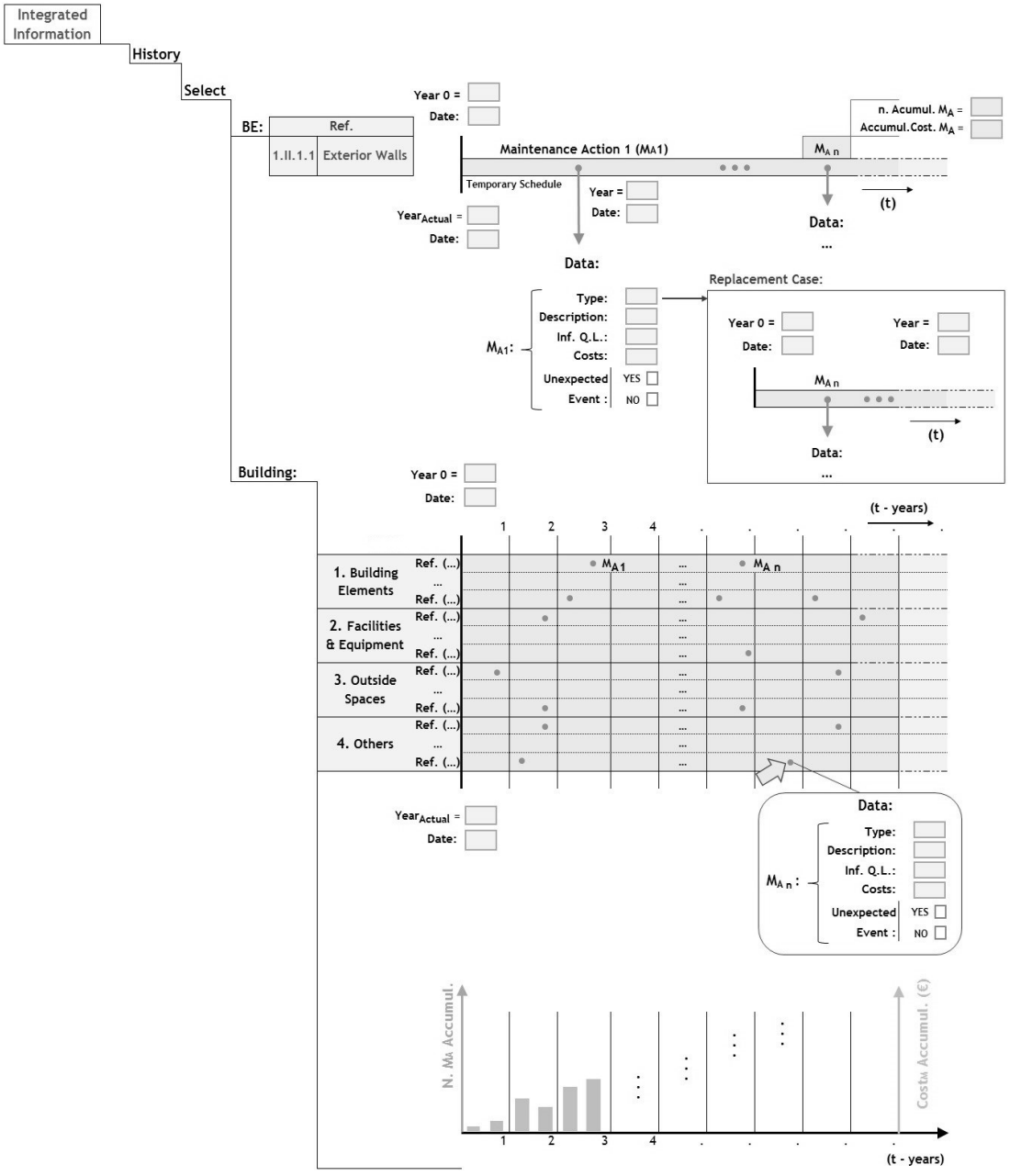

Figure 6. Graphic proposal for the representation of the Integrated Information

5. Comparative critical analysis – strengths and weaknesses

To check the most important aspects of convergence of the SIAPME project in relation to a wide range of reviewed subjects, a comparative critical examination was performed. The goal was to demonstrate that the proposed algorithm is a comprehensive solution, and in fact, that it effectively covers a good deal of essential areas. Therefore, the study scrutinised matching points with aspects of the BM theory and with other models, procedures, guidelines, standards and so on, mainly developed and/or applied to buildings, as analysed in Section 2.1. Indeed, in all comparisons, a broad range of points of agreement were successfully recorded. Using simple examples, the model is in line with relevant standards, such as BS 8210 (2012), consistent with the possibility of covering a broader range of facility assets and in the utilisation of ICTs, etc. The procedures of SIAPME also embrace the necessity to integrate KPIs in a similar way as suggested by Silva (2010) and Shohet and Nobili (2017). The field of the model concerned with the Management of Assets Descriptive Information (worksheet with the Buildings General Data) is planned to take into consideration methods like MAEC (Pedro et al., 2008; Vilhena, 2011) and SIAPME's overall characteristics seem to be in compliance with the MM framework as advised by the QDHPW (2018).

Also, a synthesis of strengths and weaknesses of the SIAPME model was made. Thus, important advantages can be compiled as follows: an eventual conversion into a software solution will allow separation into basic modules for more personalised management of a building or of a portfolio of buildings, or to be tailored to the specific needs of maintenance manager; it will allow a clear and detailed demarcation of the manager's functions and guidelines, by defining a wide range of aspects that are not generally taken into account in other solutions; it will be possible for GMs to define strategies and to measure and control their own performance; it will predict balance sheet(s) for each activity; the SIAPME will permit full control of all BEs, through the Cadastre/Attribute Trees; it will also provide automatic mechanisms for reaction and operationalisation of maintenance inspections; it will cover all buildings, through the management of the allocation of spaces and by a detailed TMIC.

A relevant disadvantage can be linked with the innovative nature of some aspects which, in so far as they had never been materialised and applied in practice, may carry out added difficulties for its subsequent operationalisation.

6. The experimental computerised form

For study purposes only, the SIAPME experimental computerised adaptation had some developments, using at this early stage the visual basic programming language. The starting window, which opens after a login process, and a window with the basic information about the first version of this adaptation, are both displayed in Figure 7 (Version 1.0.2017). In this example, which was developed for the Supporting Resources function, it can be seen that the

core connection options are aligned with the procedures established in the pre-set algorithm, as shown in Figure 3. The general idea underlying the initial computerised arrangement is to show that the work defined for BM arising from its activity control will only be extremely efficient if the management of all Supporting Resources is performed on a highly organised system, providing relevant information about all stakeholders and components.

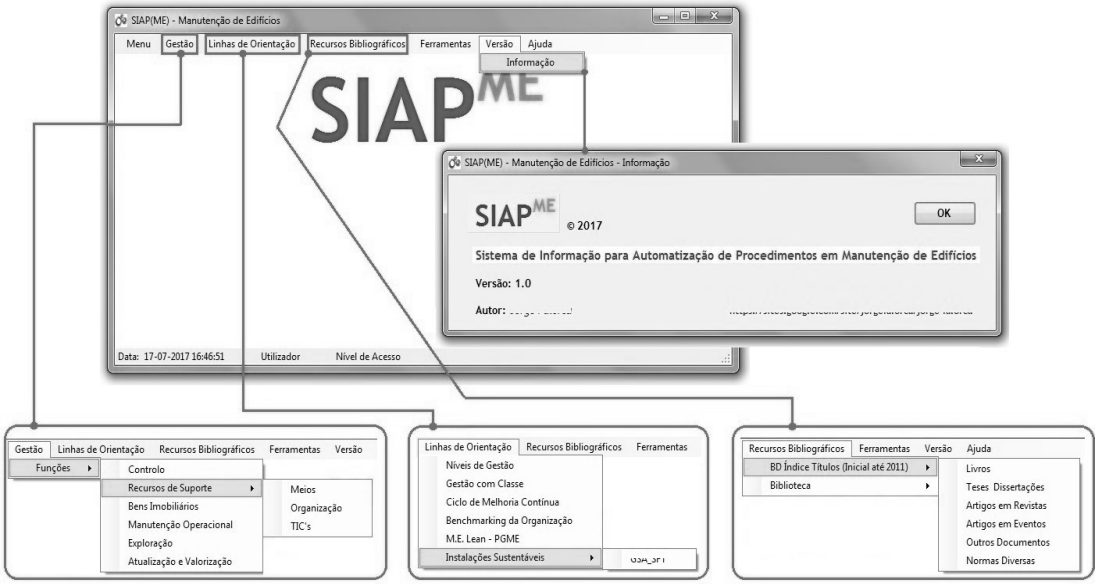

Figure 7. SIAPME computerised adaptation: the starting window and main connections (Version 1.0.2017)

7. Conclusions

This paper presented the range of a research carried out, the objective of which was to outline an algorithm of procedures, taken essential to the main functions of BM.

The bases of the methodological approach were presented, being characterised essentially by two main phases: the state-of-the-art, in which a comprehensive research on different theoretical perspectives was conducted; and the development of a system model generically called SIAPME.

With respect to the key aspects of the literature review, some important approaches within the context of models and systems with interest in the field of buildings were discussed, as well as different matters against the background of ICTs. Focusing on the technological trends to support BMM in general, a brief bibliographical account was made, addressing after, other considerations regarding computer applications and software. Still under this agenda, BIM was regarded as an area of increasing research and development. An introspective analysis was described, mainly in the sense of understanding BIM's growing involvement in the buildings usage phase, as well as the potential compatibility of the system. The main features of SIAPME were presented in Section 4, summarising its functional extension, the role of the GM and highlighting certain action lines. To verify important aspects of agreement between the

model and several of the issues reviewed, a comparative critical analysis has also been completed, which, due to the volume of material available, is presented here in general terms. However, as referred to in Section 5, there are promising results recorded.

The SIAPME's ambitious goal is to serve as a well-founded strategic basis for the development of a unique software solution. Based on innovative design and comprehensive integration of information, this model is considered viable. An important underlying goal was to find a structure of procedures which make it possible for the simplification of the functional performance of any organisation, regardless of its size. On the other hand, the algorithm was also intended to take advantage of the use of a whole set of new technologies to support its functions. Even from the understanding taken of the current stage of BIM development throughout the life cycle of buildings, it is believed that the SIAPME model's characteristics may be compatible with this tool. Thus, when considering it as a valid instrument, important developments can still be achieved, particularly in the maintenance stage of buildings.

This research has also made it possible to realise that many of the key issues of current knowledge have not yet been fully brought into the design and operation of information systems, mostly those more geared to the BM spectrum. This question is felt more strongly at the level of typical methods developed for the industrial field, which could prove useful in further developments and which, of course, will only take effect after the required adjustments have be implemented.

Although in practical terms, the SIAPME algorithm still lacks empirical validation, which would be a lengthy process; initiatives have begun in that direction.

In a comprehensive way, this research intends to contribute to the development of knowledge, particularly through a proposal aiming to optimise the multiple aspects involved in a BM framework. In some Southern European countries, such as Portugal, the application of strategies as those described above, may have significant impact, especially in economic and social terms, as in the paradigm change in the way a building in service is viewed.

References

Ahn, D. and Cha, H. (2014), "Integration of building maintenance data in application of building information modeling (BIM)", Journal of Building Construction and Planning Research, Vol. 2 No. 2, pp. 166-172.

Akasah, Z., Shamsuddin, S., Rahman, I. and Alias, M. (2009), "School building maintenance strategy: a new management approach", Malaysian Technical Universities Conference on Engineering and Technology (MUCEET 2009), Kuantan, pp. 1-5.

Aldairi, J. (2017), "The design and development of a knowledge-based lean six sigma maintenance system for sustainable buildings", PhD thesis, Faculty of Engineering and Informatics, University of Bradford, Bradford.

Alwan, Z. (2016), "BIM performance framework for the maintenance and refurbishment of housing stock", Structural Survey, Vol. 34 No. 3, pp. 242-255.

Amannah, C. (2017), “Management information system for real estate and property management”, International Journal of Computer Science and Mathematical Theory, Vol. 3 No. 1, pp. 40-70.
Au-Yong, C., Ali, A. and Chua, J. (2016), “Interval of routine maintenance and maintenance performance: a literature review”, MATEC Web of Conferences 2016, Vol. 66, Kuala Lumpur, Malaysia.
Aziz, N., Nawawi, A. and Ariff, N. (2016a), “ICT Evolution in facilities management (FM): building information modelling (BIM) as the latest technology”, Procedia – Social and Behavioral Sciences, Vol. 234, pp. 363-371.
Aziz, N., Nawawi, A. and Ariff, N. (2016b), “Building information modelling (BIM) in facilities management: opportunities to be considered by facility managers”, Procedia – Social and Behavioral Sciences, Vol. 234, pp. 353-362.
Barbosa, M., Pauwels, P., Ferreira, V. and Mateus, L. (2016), “Towards increased BIM usage for existing building interventions”, Structural Survey, Vol. 34 No. 2, pp. 168-190.
Bonetto, R. and Sauce, G. (2005), Gestion de patrimoine immobilier. Les activités de references, CSTB, Q7 Université de Savoie (referred to by Silva, 2010).
Bortolini, R. and Forcada, N. (2018), “Building inspection system for evaluating the technical performance of existing buildings”, Journal of Performance of Constructed Facilities, Vol. 32 No. 5, pp. 1-14.
Bortolini, R., Forcada, N. and Macarulla, M. (2016), “BIM for the integration of building maintenance management: a case study of a university campus”, Proceedings of the 11th European Conference on Product and Process Modelling (ECPPM 2016), Limassol, pp. 427-434.
BS 8210 (2012), Guide to Facilities Maintenance Management, The British Standards Institution (BSI, London).
BS EN 13306 (2017), Maintenance – Maintenance Terminology, The British Standards Institution (BSI), London, UK.
Carbonari, A., Corneli, A., Di Giuda, G., Ridolfi, L. and Villa, V. (2018), “BIM-based decision support system for the management of large building stocks”, 35th International Symposium on Automation and Robotics in Construction (ISARC 2018), Berlin, pp. 348-355.
Cattell, K., McGaffin, R., Michell, K. and Musambachime, K. (2004), “Computer self-efficacy and the use of maintenance management information systems”, CIBW70 2004 Hong Kong International Symposium, pp. 369-375.
Cecconi, F., Moretti, N., Maltese, S. and Tagliabue, L. (2018), “A BIM-based decision support system for building maintenance”, in Mutis, I. and Hartmann, T. (Eds), Advances in Informatics and Computing in Civil and Construction Engineering, Springer, Cham, pp. 371-378.
Chang, C. and Tsai, M. (2013), “Knowledge-based navigation system for building health diagnosis”, Advanced Engineering Informatics, Vol. 27 No. 2, pp. 246-260.
Che-Ghani, N., Myeda, N. and Ali, A. (2016), “Operations and maintenance cost for stratified buildings: a critical review”, MATEC Web of Conferences 2016, Vol. 66, Kuala Lumpur, Malaysia.
Cheng, J., Chen, W., Tan, Y. and Wang, M. (2016), “A BIM-based decision support system framework for predictive maintenance management of building facilities”, 16th International Conference on Computing in Civil and Building Engineering (ICCCBE2016), 6 - 8 July, Osaka.
Chong, A., Mohammed, A., Abdullah, M. and Rahman, M. (2018), “Maintenance prioritization – a review on factors and methods”, Journal of Facilities Management, Vol. 17 Issue: 1, pp.18-39.
Christiansen, B. (2018), “4 Biggest building maintenance challenges and solutions”, Webpage, Buildings, Stamats Communications, available at: www.buildings.com/news/industry-news/articleid/21564/title/building-maintenance-challenges-solutions (accessed 1 February 2019).
Cooper, J. (2015), “Sustainable building maintenance within social housing”, PhD Thesis, University of Greenwich, London.
Cooper, J. and Jones, K. (2008), “Routine maintenance and sustainability of existing social housing”, CIB W070 Conference in Facilities Management, Heriot Watt University, Edinburgh, pp. 361-368.

DCLG (2006), A Decent Home: Definition and Guidance for Implementation, Department for Communities and Local Government, London.
De Medici, S. and Senia, C. (2015), "Streamlining of maintenance facilities for the university real estate", TECHNE – Journal of Technology for Architecture and Environment, Issue 9, pp. 267-273.
Dixneuf, H., Soyer, I. and Segrétain, J. (2014), La maintenance des bâtiments en 100 fiches pratiques, Éd. Le Moniteur, Paris, France, available at: http://boutique.lemoniteur.fr/la-maintenance-desbatiments-en-100-fiches-pratiques-2014.html (accessed 7 February 2019).
Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011), BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 2nd ed., Wiley, Hoboken, New Jersey, U.S.A. (referred to by Ilter and Ergen, 2015).
Ebbesen, P. (2016), "Adding value to facilities management with information technology", PhD dissertation, DTU Management, The Technical University of Denmark, Kgs. Lyngby, Denmark.
EN 15331 (2011), "Criteria for design, management and control of maintenance services for buildings", European Committee for Standardization (CEN), Brussels.
Enshassi, A. and Shorafa, F. (2015), "Key performance indicators for the maintenance of public hospitals buildings in the Gaza Strip", Facilities, Vol. 33 Nos 3/4, pp. 206-228.
Falorca, J., Rodrigues, R. and Silva, R. (2011), "A utilidade das aplicações informáticas na gestão da manutenção de edifícios", 2° Fórum Internacional de Gestão da Construção – GESCON 2011: Sistemas de Informação na Construção, Secção de Construções Civis, FEUP, Porto.
Falorca, J., Rodrigues, R. and Silva, R. (2013a), "Building maintenance and management – theoretical aspects and correlations", ICEUBI 2013 – International Conference on Engineering in UBI, 27 – 29 November, Covilhã.
Falorca, J., Rodrigues, R. and Silva, R. (2013b), "Lean building maintenance – proposal for a conceptual approach", ICEUBI 2013 Proceedings of International Conference on Engineering, 27 – 29 November, Covilhã.
Falorca, J., Rodrigues, R. and Silva, R. (2014), "Research measurement of knowledge advances in building maintenance issues", Structural Survey, Vol. 32 No. 1, pp. 61-71.
FMA (2012), Facilities Management – Good Practice Guide, Facility Management Association of Australia, Melbourne, Australia.
Galán, M. and Gómez, E. (2018), "A review of maintenance management models: application for the clinic and hospital environment", The International Journal of Engineering and Science (IJES), Vol. 7 No. 9, pp. 1-17.
Gaspar, D. (2003), A análise organizacional na especificação dos sistemas de informação em gestão da manutenção, Dissertação de Mestrado em Gestão Industrial, FEUP, Porto.
GEBALIS (2017), "Relatório de atividades e contas 2017", GEBALIS, Lisboa, Portugal.
GEBALIS (2018), "Obras", available at: www.gebalis.pt/moradores/OmeuBairro/Obras/Paginas/default.aspx (accessed 6 February 2019).
GN (n.d.), "Basics on Dutch housing", Government of the Netherlands, available at: www.government.nl/topics/investing-in-dutch-housing/basics-dutch-housing (accessed 8 February 2019).
Goedknegt, D. and Ravesteijn, P. (2016), "Towards results-oriented maintenance processes at Dutch housing associations", 33rd CIB W78 Conference 2016, 31 October – 2 November, Brisbane.
Gonçalves, C. (2014), Gestão da manutenção de edifícios: modelos para uma abordagem LARG (Lean, Agile, Resilient e Green), Tese de Doutoramento, Instituto Superior Técnico, Lisboa.
Gov.UK (2018), "Good estate management for schools", Gov.UK, Department for Education, London, UK, available at: www.gov.uk/guidance/good-estate-management-for-schools (accessed 8 February 2019).
Gov.UK (n.d.), "Collection housing health and safety rating system (HHSRS) guidance", Gov.UK, Ministry of Housing, Communities and Local Government, London, UK, available at: www.gov.uk/government/collections/housing-health-and-safety-rating-system-hhsrs-guidance (accessed 7 February 2019).

GSA (n.d.), “Sustainable facilities tool”, General Services Administration, Washington, U.S.A., available at: https://sftool.gov (accessed 5 February 2019).
Housing Europe (2010), “Country profile – social housing in Europe – the Netherlands”, European Federation of Public, Cooperative and Social Housing, Brussels, available at: www.housingeurope.eu/resource-117/social-housing-in-europe (accessed 8 February 2019).
Hunt, G. (2016), “Comprehensive facility operation & maintenance manual”, WBDG, National Institute of Building Sciences (NIBS), Washington, U.S.A., available at: www.wbdg.org/facilities-operations-maintenance/comprehensive-facility-operation-maintenance-manual (accessed 7 February 2019).
Ilter, D. and Ergen, E. (2015), “BIM for building refurbishment and maintenance: status and research directions”, Structural Survey, Vol. 33 No. 3, pp. 228-256.
Ismail, Z. (2014), “Improving maintenance management practices for building facility”, Journal of Construction Engineering and Project Management, Vol. 4 No. 3, pp. 21-32.
Ismail, Z. and Kasim, N. (2013), “Implementation of information and communication technology (ICT) for building maintenance”, 1st FPTP Postgraduate Seminar 2013, Fakulti Pengurusan Teknologi dan Perniagaan, Universiti Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia, available at: http://eprints.uthm.edu.my/5780/ (accessed 11 February 2019).
ISO 29481-1 (2016), “Building information modeling – information delivery manual – Part 1: methodology and format”, International Organization for Standardization, Geneva.
ISO 55001 (2014), “Asset management – management systems – requirements”, International Organization for Standardization, Geneva.
Jandali, D. and Sweis, R. (2019), “Factors affecting maintenance management in hospital buildings: perceptions from the public and private sector”, International Journal of Building Pathology and Adaptation, Vol. 37 No. 1, pp. 6-21.
Jones, K. and Collis, S. (1996), “Computerized maintenance management systems”, Property Management, Vol. 14 No. 4, pp. 33-37.
Kelly, G., Serginson, M., Lockley, S., Dawood, N. and Kassem, M. (2018), “BIM for facility management: a review and a case study investigating the value and challenges”, 13th International Conference on Construction Applications of Virtual Reality, 30–31 October 2013, London.
Lam, E., Chan, A. and Chan, D. (2010), “Benchmarking success of building maintenance projects”, Facilities, Vol. 28 Nos 5/6, pp. 290-305.
Lanzinha, J. and Freitas, V. (2009), “Performance-based diagnosis applied to the rehabilitation of residential buildings”, Journal of Building Appraisal, Vol. 5 No. 2, pp. 133-148.
Lateef, Olanrewaju A. and Abdul-Aziz, A. (2015), “Building maintenance processes, principles, procedures, practices and strategies”, Building Maintenance Processes and Practices, Springer, pp. 79-129.
Lee, G., Sacks, R. and Eastman, C. (2006), “Specifying parametric building object behavior (BOB) for a building information modeling system”, Automation in Construction, Vol. 15, pp. 758-776.
Lohmann, H., Jensen, P. and Gregg, J. (2017), “Transferring knowledge from building operation to design: a literature review”, CIB World Congress 2017, Salford.
Madritsch, T. and May, M. (2009), “Successful IT implementation in facility management”, Facilities, Vol. 27 Nos 11/12, pp. 429-444.
Marquez, A. and Gupta, J. (2006), “Contemporary maintenance management: process, framework and supporting pillars”, Omega, Vol. 34 No. 3, pp. 313-326.
Matarneh, S., Danso-Amoako, M., Al-Bizri, S., Gaterell, M. and Matarneh, R. (2018), “Developing an interoperability framework for building information models and facilities management systems”, in Hajdu, M. and Skibniewski, M. (Eds), Proceedings of the Creative Construction Conference 2018, Ljubljana, pp. 1018-1027.
MENESR (2014), “Optimiser et rénover le patrimoine immobilier universitaire”, Guide méthodologique, Ministère de l’Education Nationale, de l’Enseignement Supérieur et de la Recherche, Paris.
MHCLG (2018), A New Deal for Social Housing, Social Housing Team, Ministry of Housing, Communities and Local Government, London.

Mirarchi, C., Pavan, A., De Marco, F., Wang, X. and Song, Y. (2018), "Supporting facility management processes through end-users' integration and coordinated BIM-GIS technologies", ISPRS International Journal of Geo-Information, Vol. 7 No. 191, pp. 1-20.
Molinari, C., Paganin, G. and Talamo, C. (2002), "Information systems for real estate management", Proceedings of the CIB W070 2002 Global Symposium, CIB and CABER, Caledonian University, Glasgow, pp. 349-362.
Muczyński, A. (2016), "A comprehensive model of municipal housing stock management", Real Estate Management and Valuation, Vol. 24 No. 2, pp. 57-71.
Mydin, M. (2017), "Significance of building maintenance management on life-span of buildings", Robotica and Management, Vol. 22 No. 1, pp. 40-44.
Natário, A. (2016), Decision Model for Maintenance Management of Buildings of Santa Casa da Misericórdia de Lisboa, Extended abstract to obtain the Master of Science Degree, Instituto Superior Técnico (IST), Lisboa.
Neelamkavil, J. (2009), "A review of existing tools and their applicability to facility maintenance management", Report No. RR-285, Institute for Research in Construction – National Research Council of Canada, Ottawa, September 2009.
Nelson, M., Anumba, C. and Aziz, Z. (2006), "Towards next-generation facilities management systems", Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montréal, pp. 906-917.
NP 4483 (2009), Guia para a implementação do sistema de gestão da manutenção, Instituto Português da Qualidade (IPQ), Caparica, Portugal.
Olanrewaju, A., Fang, W. and Tan, S. (2018), "Hospital building maintenance management model", International Journal of Engineering & Technology, Vol. 7 No. 2.29, pp. 747-753.
Omar, M., Ibrahim, F. and Omar, W. (2016), "An assessment of the maintenance management effectiveness of public hospital building through key performance indicators", Sains Humanika, Vol. 8 Nos 4-2, pp. 51-56.
Pärn, E., Edwards, D. and Sing, M. (2016), "The building information modelling trajectory in facilities management: a review", Automation in Construction, Vol. 75, pp. 45-55.
PE (n.d.), "Manutenção", Parque Escolar, available at: www.parque-escolar.pt/pt/programa/manutencao-apresenta.aspx (accessed 6 February 2019).
Pedro, A., Paiva, J. and Vilhena, A. (2008), "Portuguese method for building condition assessment", Structural Survey, Vol. 26 No. 4, pp. 322-335.
Puķīte, I. and Geipele, I. (2017), "Different approaches to building management and maintenance meaning explanation", Procedia Engineering, Vol. 172, pp. 905-912.
QDHPW (2018), "Maintenance management framework", Policy for the maintenance of Queensland Government buildings, available at: www.hpw.qld.gov.au/SiteCollectionDocuments/MMF.pdf (accessed 22 January 2019).
Raposo, S., Brito, J. and Fonseca, M. (2012), "Sistemas de gestão de manutenção de edifícios – uma análise sobre as práticas adoptadas internacionalmente", Congresso da Construção 2012, Coimbra.
Raposo, S., Fonseca, M. and Brito, J. (2011), "Planned preventive maintenance activities: analysis of guidance documents", 12th International Conference on Durability of Building Materials and Components (DBMC), 12–15 April, Porto.
RICS (2019), "BCIS: economic significance of maintenance", Royal Institution of Chartered Surveyors, available at: www.rics.org/uk/news-insight/latest-news/news-opinion/bcis-economicsignificance-of-maintenance/ (accessed 15 February 2019).
Sagoo, A. (2014), "A decision support system for evaluating local authority housing maintenance strategies in the United Kingdom", PhD thesis, University of Derby, Derby, UK.
Sampaio, A. (2016), "Building maintenance supported on virtual reality environments: roofs and walls", Journal of Civil Engineering and Architecture, Vol. 10 No. 1, pp. 1-12.
Sampaio, A. (2018), "Enhancing BIM methodology with VR technology", in Mohamudally, N. (Ed.), State of the Art Virtual Reality and Augmented Reality Knowhow, IntechOpen, London, pp. 59-79.
Sampaio, A., Simões, D. and Berdeja, E. (2016), "BIM tools used in maintenance of buildings and on conflict detection", in Delgado, J. (Ed.), Sustainable Construction. Building Pathology and Rehabilitation, Vol. 8, Springer, pp. 163-183.

Santos, R., Costa, A. and Grilo, A. (2017), “Bibliometric analysis and review of building information Q13 modelling literature published between 2005 and 2015”, Automation in Construction, Vol. 80, pp. 118-136.
SGV (n.d.), “School policy and advisory guide”, State Government of Victoria, Education and Training, available at: www.education.vic.gov.au/school/principals/spag/Pages/spag.aspx (accessed 8 February 2019).
Sherwin, D. (2000), “A review of overall models for maintenance management”, Journal of Quality in Maintenance Engineering, Vol. 6 No. 3, pp. 138-164.
Shohet, I. and Lavy, S. (2017), “Facility maintenance and management: a health care study case”, International Journal of Strategic Property Management, Vol. 21 No. 2, pp. 170-182.
Shohet, I. and Nobili, L. (2017), “Application of key performance indicators for maintenance management of clinics facilities”, International Journal of Strategic Property Management, Vol. 21 No. 5, pp. 58-71.
Silva, A. and Brito, J. (2019), “Do we need a buildings’ inspection, diagnosis and service life prediction software?”, Journal of Building Engineering, Vol. 22, pp. 335-348.
Silva, R. and Falorca, J. (2009), “A model plan for buildings maintenance with application in the performance analysis of a composite facade cover”, Construction and Building Materials, Vol. 23 No. 10, pp. 3248-3257.
Silva, S. (2010), A gestão da actividade de manutenção em edifícios públicos – modelo e definição de estratégias para uma intervenção sustentável, Tese de Doutoramento, Instituto Superior Técnico, Lisboa.
Straub, A. (2002), “Strategic technical management of housing stock: lessons from Dutch housing associations”, Building Research & Information, Vol. 30 No. 5, pp. 372-381.
Straub, A. (2012), “Maintenance and repair”, in Smith, S., Elsinga, M., O’Mahony, L., Seow Eng, O., Wachter, S. and Lovell, H. (Eds), International Encyclopedia of Housing and Home, Vol. 4, Elsevier, Oxford, pp. 186-194.
Straub, Ad. (2009), “Dutch standard for condition assessment of buildings”, Structural Survey, Vol. 27 No. 1, pp. 23-35.
Taillandier, F., Sauce, G. and Bonetto, R. (2011), “Method and tools for building maintenance plan arbitration”, Engineering, Construction and Architectural Management, Vol. 18 No. 4, pp. 343-362.
Taillandier, F., Abi-Zeid, I., Taillandier, P., Sauce, G. and Bonetto, R. (2014), “An interactive decision support method for real estate management in a multi-criteria framework – REMIND”, International Journal of Strategic Property Management, Vol. 18 No. 3, pp. 265-278.
Teicholz, P. (2013), BIM for Facility Managers, John Wiley & Sons, Hoboken, New Jersey, U.S.A. (referred to by Matarneh et al., 2018).
Vijverberg, G. (2002), “Renovation of offices in the Netherlands: reasons, points for attention and obstacles”, CIB W070 2002 Global Symposium, CIB and CABER, Caledonian University, Glasgow, pp. 728-737.
Vijverberg, G. (2004), “Strategic housing stock policy and maintenance management practice in Dutch social housing”, CIBW70 2004 Hong Kong International Symposium, 7-8 December, Hong Kong.
Vilhena, J. (2011), Método de avaliação do estado de conservação de edifícios – análise e contributos para o seu aperfeiçoamento e alargamento do âmbito, Tese de Doutoramento, Instituto Superior Técnico, Lisboa.
Volk, R., Stengel, J. and Schultmann, F. (2014), “Building information modeling (BIM) for existing buildings – literature review and future needs”, Automation in Construction, Vol. 38, pp. 109-127.
Wang, X. (2017), “Subtopic: developing a total building maintenance framework through benchmarking”, Project Report, Sustainable Built Environment National Research Centre (SBEnrc), Perth.
Wing, A., Mohammed, A. and Abdullah, M. (2016), “A review of maintenance priority setting methods”, International Journal of Real Estate Studies, Vol. 10 No. 2, pp. 35-43.
Wood, B. (2005), “Towards innovative building maintenance”, Structural Survey, Vol. 23 No. 4, pp. 291-297.

Woodward, C. and Kuula, T. (2015), “Mobile augmented reality for building maintenance”, in Airaksinen, M. and Kokkala, M. (Eds), Smart City – Research Highlights, VTT Technical Research Centre of Finland Ltd, Espoo, pp. 46-47.
Wordsworth, P. (2001), Lee’s Building Maintenance Management, 4th ed., Blackwell Science, London (referred to by Lam et al., 2010).
Yin Lee, H. and Scott, D. (2008), “Identification of main aspects in the management of building maintenance operation processes”, Surveyors Times, Vol. 17 No. 6, pp. 37-41.
Yin Lee, H. and Scott, D. (2009), “Strategic and operational factors’ influence on the management of building maintenance operation processes in sports and leisure facilities, Hong Kong”, Journal of Retail & Leisure Property, Vol. 8 No. 1, pp. 25-37.
Zakiyudin, M., Fathi, M., Tobi, S. and Rambat, S. (2016), “Building maintenance information systems: the adaptation of context aware technology”, International Journal of Research in Chemical, Metallurgical and Civil Engineering, Vol. 3 No. 1, pp. 90-93.

3.5. An integrated approach to the supporting resources function of an information system for building maintenance management

Contribution:

Falorca, J.,

An integrated approach to the supporting resources function of an information system for building maintenance management, in: ICEUBI 2017, International Conference on Engineering, a Vision for the Future, 2017, December 5-7, University of Beira Interior, Covilhã, Portugal.

An integrated approach to the supporting resources function of an information system for building maintenance management

Jorge Falorca; jorge.falorca@netvisao.pt
Jorge Falorca, Civil Engineer, MSc Construction Sciences.

Abstract

The implementation of the building maintenance operations and its logistic management, require the optimisation of all related resources. Such involves great potential if scientifically, well-founded methodologies are used, alongside with computerised means, thus enabling fully integration of information. Following along with this idea, a research work was carried out to introduce an algorithm of procedures as a networking basis for a comprehensive information system, able to be used in the over-all management of real estate assets. This project was generically called Information System for Automatisation of Procedures in the Building Maintenance Management. The Supporting Resources is one of the six main foreseen functions of management and its importance is fundamental for the complete success of the proposed approach. As a first outcome of the drafted algorithm, this article presents the main guidelines for this function, which in the meantime are being adapted in an experimental computerised form. The results achieved provide evidence of its potentialities, especially concerning the effectiveness of the own procedures and the sustainable integration of all necessary information to manage.

Keywords: Building maintenance management; information systems; review; algorithm of procedures.

1. Introduction

Over the past few decades, important developments have occurred in the field of Communication and Information Technologies (ICTs), from which the building maintenance management activity has also been able to take great advantages.

An in-depth review on this interaction has already been performed [1], regardless of the issue having a wide-ranging background. In a subsequent study, an analysis of key aspects by targeting perspectives has been done. From that research, important approaches within the framework of models and systems with interest in the field of buildings could be found, of which, stands out those implemented in the campus of the University of Savoy, France [2], in the U.K.'s school built sets [3], in the Victoria State in Australia [4] and in the U.K.'s social housing case [5], etc.

In addition, several other matters reviewed against the background of ICTs could be described. There are technological applications to support the building maintenance management in general, which the two most well-known are the CAFM – Computer-Aided Facility Management and the CMMS – Computer Maintenance Management Systems. Also, several trends visions within literature related with maintenance systems were studied. In this regard, it may be cited, for example, a critical review of existing CAFM system [6]; an analysis of characteristics that can aid in the selection of a CMMS [7]; a review about existing tools and their applicability to facility maintenance management [8]; the CMMSs needs of using, its capabilities and benefits [9]; and a methodology for the analysis, design and implementation of building maintenance management systems, including a supporting information system [10]. Within the range of computer applications for public purposes, it could be emphasised the DicPla [11], PGMe [12] and SIGMO [13] programs.

About commercial software, an idea of the wide range of available products can be get, by consulting, for example, the website of the Software Advice company [14]. Furthermore, it can still find worldwide many other solutions, each one with its own peculiarities.

In the Building Information Modelling (BIM) context and specially focused on the main issues related with our study (building maintenance, FM, asset management, existing buildings), there has already been important developments. It is worth to mentioning the article of Volk et al. [15], which provides a deep literature review and future needs under the scope of BIM for existing buildings, as well the overview carried out by Ilter and Ergen [16] about the current literature on BIM for building refurbishment and maintenance.

Thus, in result of the literature review, it was possible to get the perception that the available market possibilities of software or related applications are currently of broad ranging, with different approaches in terms of integration, functions, and degrees of success. But on the scope of the constructive elements and on many other issues, as the ones related with environment, sustainability, energy, comfort and on an increasingly stringent legislation, a shortage of applications is still found, thus not allowing a wider and flexible utilization, based on models scientifically studied and tested.

In this sense and because a basic activity of building maintenance management should not be performed in an improvised and casual way, it appears to be essential the emergence and development of contributions aimed at improving the real estate asset management methods, mainly through proper planning of processes and activities. For such purpose, it was developed a system plan entitled as Information System for Automatization of Procedures in the Building Maintenance Management - initials in Portuguese: SIAP(ME). Basically, it is an algorithm of well-founded procedures, which strategies were developed through a set of interconnected files with extension .xls. Based on the SIAP(ME)'s model, an experimental computerised adaptation is already under development.

This article presents some important lines of the SIAP(ME), particularly those directed to the Supporting Resources function, as well the developments already introduced on its experimental computerised adaptation. The general idea is to show that both the work defined for building maintenance as that arising from its activity control, will only be extremely efficient if the management of all Supporting Resources be performed based on a very well-organised system, providing the most suitable information about all stakeholders and components.

2. SIAP(ME)'s algorithm functional basis

2.1. Main sector areas

The SIAP(ME)'s algorithm of procedures comprises a functional basis of interaction of four sector areas, as it is highlighted at Table 1.

On this case, the Users are expected to be able to interact with each other or with the computer platform, through direct access to the central server or remotely via the Internet - considering the Web Based system. For instance, Level 0 - GGN0 General Managers (who are at the top of the hierarchy) can have access to all the system fields. In any other case, the access has partial constraints, meeting each type of Users' needs. Also, notice that behind the Management (and the Real Estate) there is an Organization, which may be considered the Property Owner or a Contracted Management Company.

2.2. The General Manager

Within the SIAP(ME)'s algorithm, it is foreseen that the General Manager's person has to perform the following generic functions:

- To inform and/or to interact with top management (General Administration or entity with other designation);
- To manage one or several Buildings and/or Built Sets (CPs) - this can be considered, basically, the management of the real estate assets;
- The management of the Outsourcing and the Interaction;

- The management of SIAP(ME) as an informatic program, mainly by the management of the system itself and of the professional relations between all stakeholders.

Table 1 - SIAP(ME)'s algorithm of procedures: the different foreseen functional areas to interact

Sector Area	Organizational "Entities" Involved		Level	Description
Management	General Administration	General Manager	GGN0 (Level:0) or GGN1 (Level:1)	He has the functions of the General Management of a Building(s) or Built Set(s) (CPs). In this case, this(ese) person(s) may also be the coordinator(s) of other sub managers to whom can still be assigned a CP (for purposes of deconcentrating) - thus being distinguishing two levels in this case.
		Internal General Services	SIGN2 (Level:2) or SIGN3 (Level:3)	It includes the internal middle positions.
		Operational Services	SOPN4 (Level:4)	It corresponds to the internal people who, in operational terms, make the maintenance on the ground.
Real State	Building(s) or Built Sets		-	It can be discriminated / identified in one (or several) Buildings or alternatively in one (or several) Built Sets.
Outsourcing	Outside Staff and Services	Companies	-	It consists of all external services also required for the asset management.
		Service Providers	-	
		Self-employed Workers	-	
Interaction	Users	General Users	Level 0 to 4 (as the case may be)	The main beneficiaries of the building maintenance also involved: the patrimony's User(s) and, by inherence, the SIAP(ME)'s User(s).
		Recognied Users	-	It comprises the outsourcing staff and services and others external users. In this case, they will have restricted access to the system.

Therefore, for this organizational "entity" in particular, it is assigned the role of General Management, whose field of action is linked to an intrinsic window (please see Figure 1).

All over his duties, there are six Main Lines which the General Manager must follow and try to fulfil. So, by clicking at:

- Management Levels - it will refer to an informative area generically covering the Strategic Level, the Tactical Level and the Operational Level;
- Class Management - it connects to an area of verification and control of some basic aspects as those used in the World Class Maintenance (WCM) model;
- Cycle of Continuous Improvement - there is a connection to an informative area intended for the constant checking and monitoring of aspects related to Strategy, Resources, Operation, Review and Continuous Development;

- Benchmarking of the Organization - in this case, an area with several steps appears, covering the Requirements of the Benchmarking Process, the Type of Benchmarking used and the Steps of the Benchmarking Process;
- Lean Building Maintenance (LBM) - the corresponding window addresses the interactions that must exist in a General Building Maintenance Management Process (BMMP), as dealt with in Falorca et al. [17];
- Sustainable Facilities - it joins to a peripheral system of information, developed in sense of getting sustainable facilities.

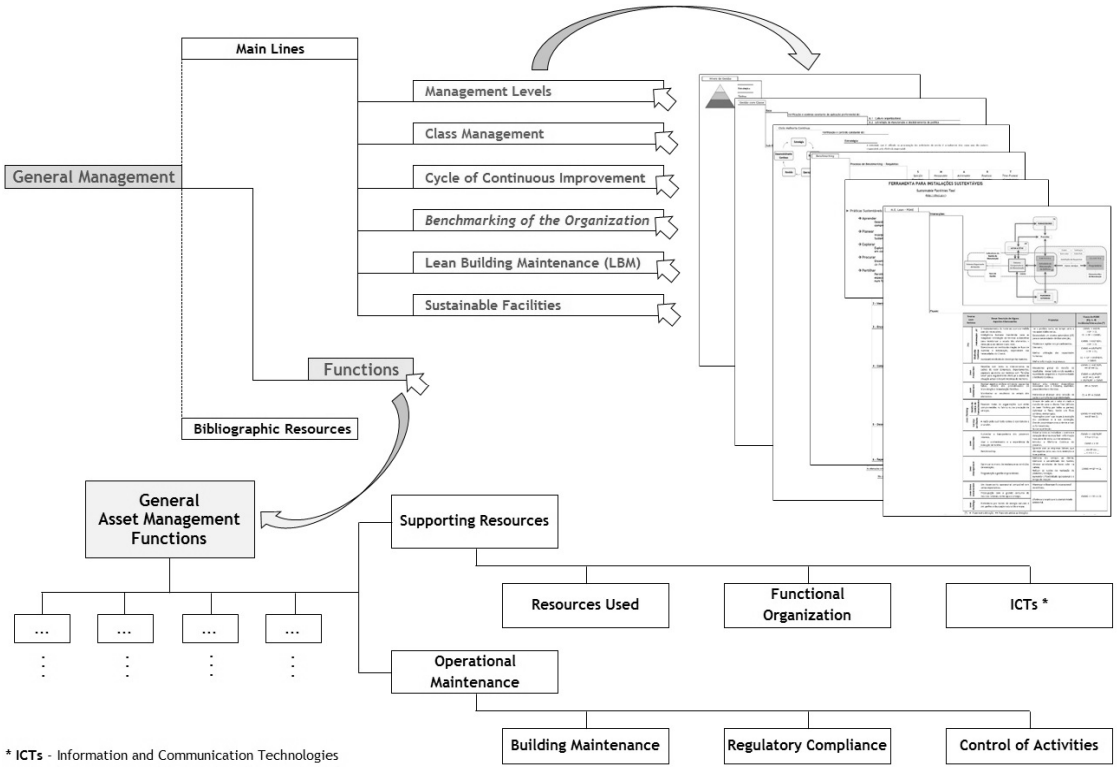

Figure 1 – SIAP(ME): schematic representation of the Main Lines and Functions in the context of the General Management

It was further provided the Bibliographic Resources option, giving full access to a database built under the study accomplished by Falorca et al. [18].

Still clicking on the option Functions, the user has access to what is considered the core of the SIAP(ME), so-called as the General Asset Management Functions, which some are represented at the bottom, in the schema of Figure 1.

3. The SIAP(ME)'s Supporting Resources function - a brief description

The General Management of a real estate assets needs to control and know, in real time, all internal resources and other used for that purpose. So, a specific management function, here

designated as Supporting Resources and indicated in the bottom of Figure 1, is expected to cover:

- The management of the Resources Used (such as the human resources, the materials, the equipment's, among others);
- The Functional Organization;
- The ICTs - particularly regarding the Operation Management of SIAP(ME), embracing the logistics as well, related with the hardware and software.

3.1. The Resources Used in the General Management

Following the previous section, the SIAP(ME)'s algorithm comprises the sub-function referred as Resources Used, consisting of:

- A register of all Human Resources required for the management work of the different assets;
- The management of knowledge about the register of Equipment's and Materials (including the Acquisition processes, the tree of equipment and materials, etc.);
- The register of the SIAP(ME) User's (General Users and Recognized Users);
- The register and management of all stakeholders in the Outsourcing process;
- The management of all assigned Codes;
- The Bibliographic Resources associated with Resources Used sub-function;
- The Performance Indicators associated with;
- The Reports Generation.

In this case, it will be also possible to get a connection with the tree of all Building Elements (BEs), mainly through the Codes Management, since each one has its own identification. A little further on, in Figure 4, the different options here described are already introduce as an important part of the SIAP(ME)'s experimental computerised adaptation.

3.2. The Functional Organization

The proposal of the Functional Organization item in the SIAP(ME), predicts the management of its Organization Chart and of all Hierarchical Dependencies (for example through the Strategic Levels). It is also envisaged to involve the Operational Procedures and the Definition of Models Type for Documentation, which the entire structure of assets management can generate and spread.

3.3. The ICTs within the SIAP(ME)

At this point, it was considered essential that the model also considers the Software Operation Management itself. It is focused essentially on the:

- Software Processes, Updating and Innovation;
- System Maintenance Plan;
- Register of the existing Infrastructures and Equipment (used inside the Organization);
- Utilisation Levels Management;
- Information Management;
- Integration of Models Type for Documentation.

4. Introducing the SIAP(ME)'s experimental computerised adaptation

4.1. Login

Arising from the implementation of the SIAP(ME)'s algorithm proposal and for study and research purposes only, an experimental computerised adaptation for the SIAP(ME)'s algorithm is already under development, using at this early stage, the Visual Basic programming language.

Thus, the login process is performed based on the user category, in accordance with the third column of Table 1. This procedure is initiated through the display of a window in which different types of users are differentiated - please see Figure 2. Depending on the situation, a second window will appear, on which can be selected the user's name and the own ID code or an input password must be inserted. If the user is properly identified, this stage will end with a welcome message.

It should be noted that the login can only be done with support on a database of users previously established (this registration system is described further in section 4.3.).

Figure 2 – The set of windows established for login on the SIAP(ME)'s computerised adaptation (Version 1.0.2017)

4.2. The introductory window for programme initiation

The starting window and the window with the basic information about the first version of this adaptation (called as Version 1.0.2017) are displayed in Figure 3.

It also can be seen that the main connection options match with the procedures established in the pre-set algorithm, as it was showed in Figure 1.

For instance, by clicking on the Help option (appearing in Figure 3 as “Ajuda”) it is allowed to review the whole algorithm, still in the original format (a set of interconnected organization charts in MS Excel sheets).

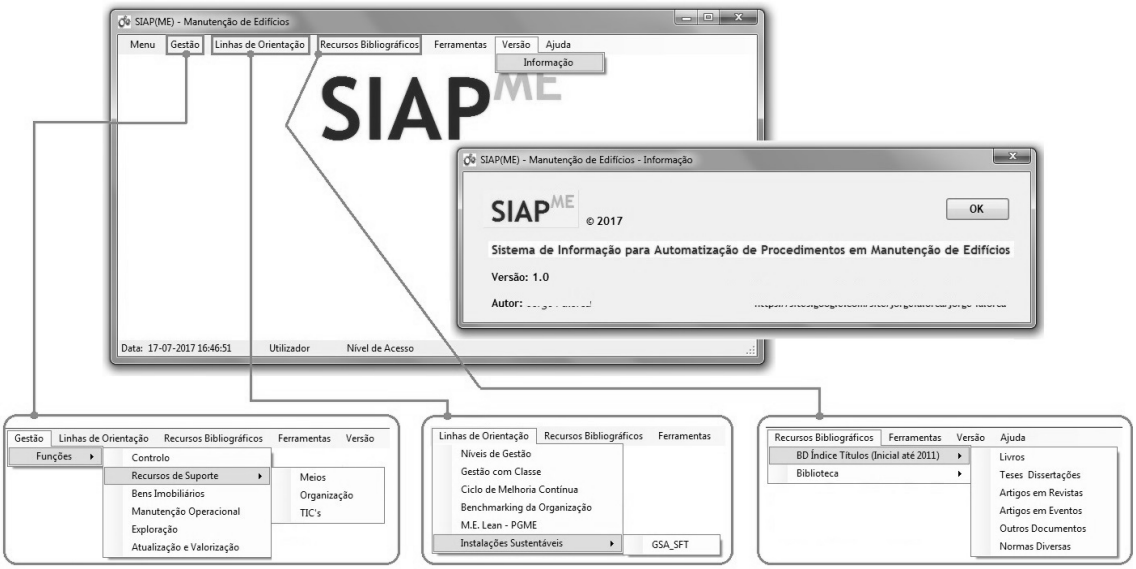

Figure 3 – SIAP(ME)’s computerised adaptation: the starting window and main connections (Version 1.0.2017)

4.3. The window of the Resources Used sub-function

As it is illustrated in Figure 4, following the options order like Management (“Gestão”) ▫ Functions (“Funções”) ▫ Supporting Resources (“Recursos de Suporte”) ▫ Resources Used (“Meios”), the respective window will appear (Figure 4).

Still in agreement with the description accomplished at section 3.1., the window referring to Resources Used (“Meios”), allows the user to access the different management options for all the resources used in the building maintenance. Therefore, it is possible to make the register of all the elements related to the generality of human resources involved in this task, as well those referring to equipment’s, materials, outsourcing agents, etc. In the opposite direction, it is possible to make a research all over the program, in order to get a view on the register information of each resource, make changes and so on.

All Resources Used, including Materials, Equipment’s and BEs will have an ID Code to which may be associated a Barcode or a QR Code.

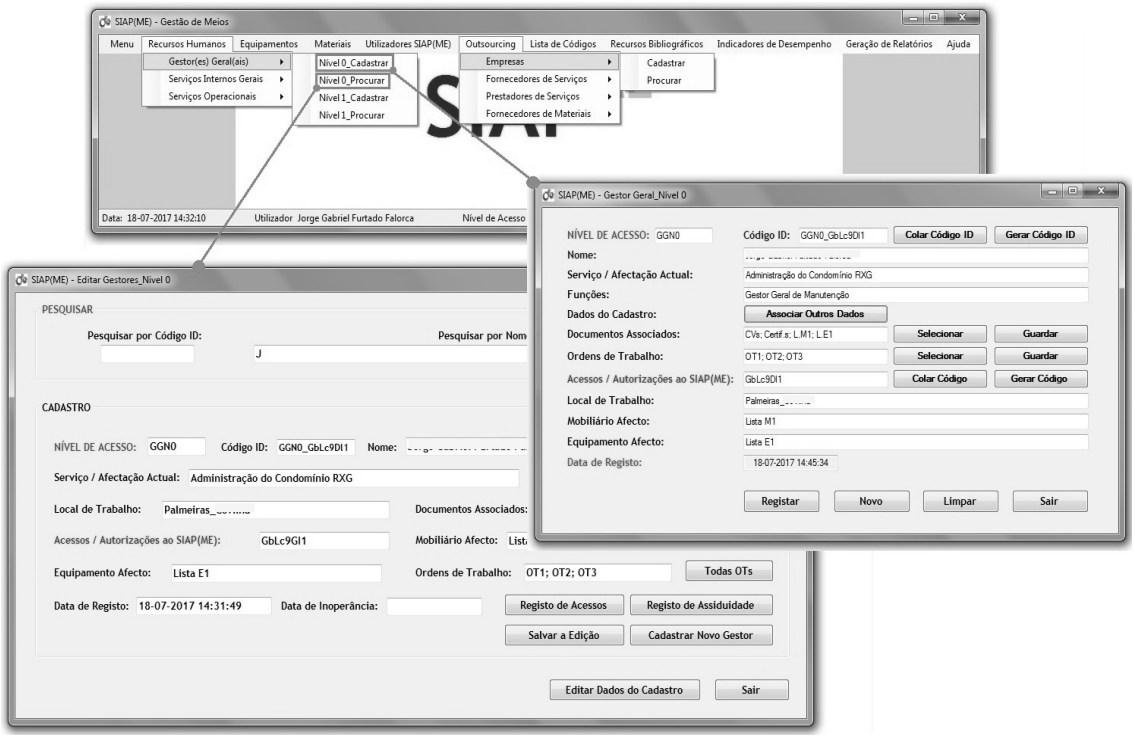

Figure 4 – SIAP(ME)'s computerised adaptation: example of windows referring to Resources Used ("Meios"), Register ("Cadastrar") and Search ("Procurar") - Version 1.0.2017

In addition, to all SIAP(ME)'s users is also assigned an access code or authorization when registering. Then, by clicking on the button ID Generate Code ("Gerar Código ID"), an additional window will be displayed with the possibility of generating Random Passwords, Barcode and QR Codes. Other options also allow to save the picture of the generated code, and even to read it, for example, through the Webcam of the computer in use. To have an idea about these procedures, Figure 5 shows the windows designed for such.

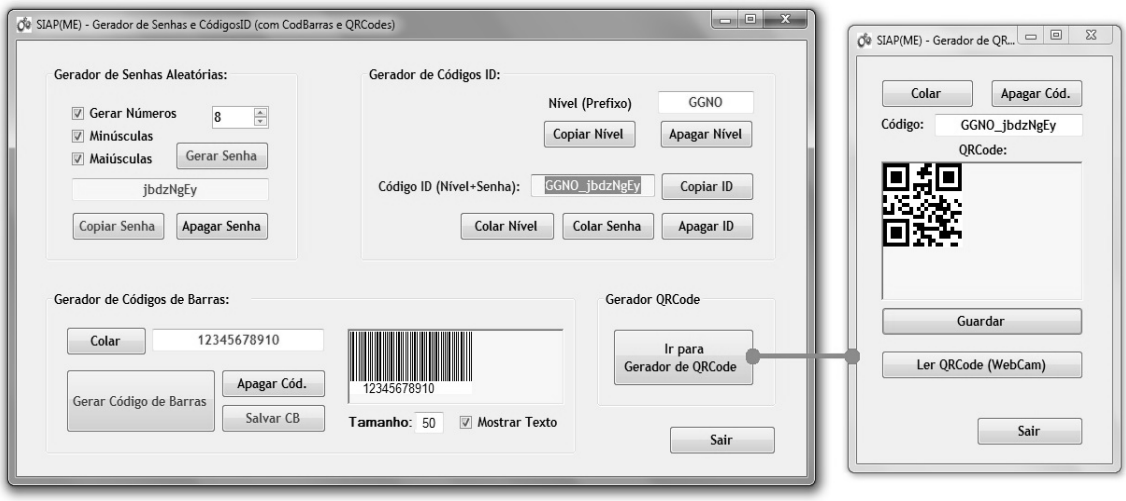

Figure 5 – SIAP(ME)'s computerised adaptation: example of windows enabling the generation of different sort of codes and random passwords (Version 1.0.2017)

The register data of each user will be complete if all personal data are associated with. To this end, by clicking the button Associate Other Data ("Associar Outros Dados") a new window arises and it will be possible to complete multiple fill fields, such as date of birth, place of birth, address, telephone numbers, etc.

5. The supporting resources information integrated within the operational maintenance

Also, as can be seen at the bottom of Figure 1, SIAP(ME)'s algorithm still predicts that the Operational Maintenance function be sectioned into Building Maintenance, Regulatory Compliance and Control of Activities.

All the information stored in the way described above for the Supporting Resources function can thus be used in an integrated manner in the context of Operational Maintenance. Specifically, the SIAP(ME)'s algorithm forecasts that the Maintenance of Buildings will be done through the Strategic Planning of Maintenance, by the Management of Maintenance Resources and by the Economic Management of Maintenance. On the other hand, the maintenance Activity Control will be essentially carried out based on the planned Work Orders (OTs) and on several complementary aspects.

One of the most important aspects to consider from this context refers to the fact that the Strategic Maintenance Planning will be grounded on the definition and compliance, for each BE, of a Strategic Maintenance Plan (in abbreviation: PEM – "Plano Estratégico de Manutenção"), mainly through the realization of a set of Strategic Maintenance Options. A proposed configuration for external walls (which eventually can embrace the most common coating solutions) is illustrated in Figure 6.

Therefore, as it is possible to infer from this background, both the work defined in each Strategic Maintenance Option for each PEM, as well as that arising from the maintenance Activity Control, will only be the most proficient if the management of all Supporting Resources be in line with an approach based on a well-structured organization.

6. Conclusion

The building maintenance management requires the use of means which guarantees absolute effectiveness of its procedures, together with the satisfaction of different sustainability goals.

This article makes known an algorithm of procedures, called SIAP(ME), whose proposal was based on an extensive literature review. Some general lines were presented, especially those related with its Supporting Resources function. Simultaneously, some aspects of an experimental computerised adaptation were described generally.

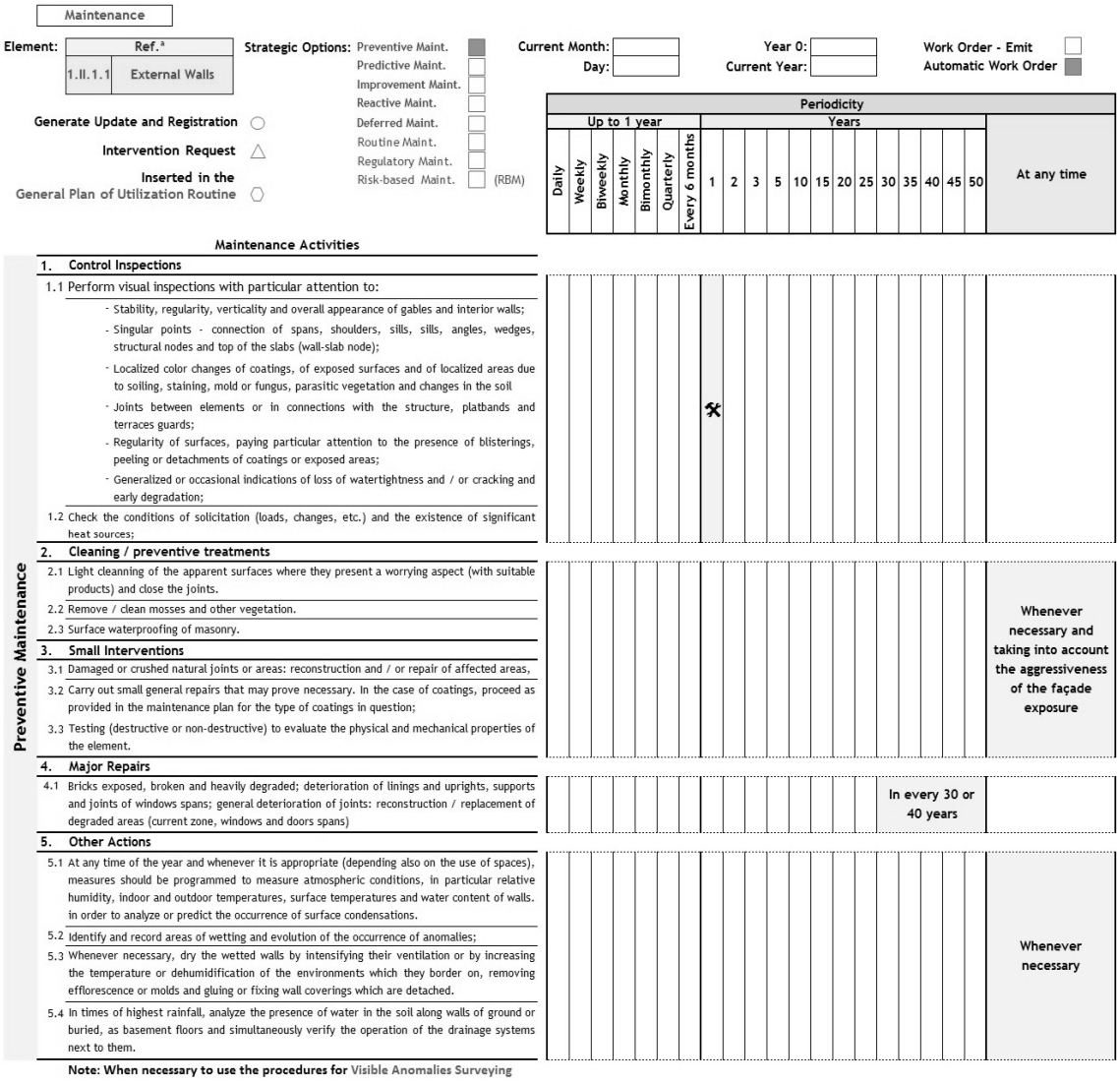

Figure 6 – SIAP(ME): example of a Strategic Maintenance Option for external walls (Preventive Maintenance case)

Resulting from this approach, some conclusions may be drawn. Firstly, the basic characteristics of the outlined model seems to be in convergence with the different sort of current models, possibly even with those positioned in the CAFM and CMMS categories. Additionally, this research can provide a valuable input for a more in-depth discussion on the identification and correction of gaps for many systems currently in use. Lastly, through the procedures established for the SIAP(ME), any building manager will be allowed to have a very broad perspective of its functions, covering nearly all the fundamental aspects for an efficient and integrated maintenance, with optimal control of all the players in the process.

In some Southern European countries, such as Portugal, the application of such strategies as some of that as above described, may have a very significant impact, especially in economic and social terms, as in the paradigm change on the way a building in service is seen.

References

[1] Falorca, J., Calejo, R., Mendes da Silva, R., A utilidade das aplicações informáticas na gestão da manutenção de edifícios. GESCON 2011 – Sistemas de Informação na Construção, Porto, Portugal, 2011.

[2] R. Bonetto, G. Sauce: Gestion de patrimoine immobilier. Les activités de references. CSTB, Université de Savoie, France, 2005 (referred by S. C. Silva. A Gestão da atividade de manutenção em edifícios públicos – modelo e definição de estratégias para uma intervenção sustentável. Tese de Doutoramento em Engenharia Civil, IST, Lisboa, Portugal, 2011).

[3] DfEE. Asset management plans. Section 1: Framework. Department for Education and Employment (DfEE) Publications, London, U.K. 2000.

[4] Smith, J.; Stewart, P.: "State-wide schools' maintenance audit in Victoria, Australia: the framework and process", Structural Survey, Vol. 25 Issue: 1 (2007), pp. 24-38.

[5] Cooper, J., Jones, K., Routine maintenance and sustainability of existing social housing. CIB W070 Conference in Facilities Management, Edinburgh, U.K., 2008.

[6] Nelson, M., Anumba, C., Aziz, Z., Towards next-generation facilities management systems. Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montréal, Canada, June 2011.

[7] Kullolli, I.: "Selecting a computerized maintenance management system". Biomedical Instrumentation & Technology, (2008), pp. 276-278.
http://biomed.partners.org/main/newsitems/cemgmt_cmms.pdf (04/05/2015).

[8] J. Neelamkavil. A review of existing tools and their applicability to facility maintenance management. Report # RR-285. Institute for Research in Construction - National Research Council of Canada, Ottawa, Ontario, 2009.
https://pdfs.semanticscholar.org/7572/9a923d8702c6c454a21d874751218bc545a9.pdf (06/06/2011).

[9] G. Sullivan, R. Pugh, A. Melendez, W. Hunt. Operations & maintenance best practices - a guide to achieving operational efficiency. Federal Energy Management Program, U.S. Department of Energy Federal, 2010.
https://energy.gov/sites/prod/files/2013/10/f3/omguide_complete.pdf (15/03/2015).

[10] J. Silva. Gestão da manutenção de edifícios – análise de processos e especificação do sistema de suporte. Relatório PDI Dissertação de Mestrado Integrado em Engenharia Electrotécnica e de Computadores Major Automação, FEUP, Porto, Portugal, 2011.

[11] ITeC. Programa para la redacción del libro del edificio y la planificación y gestión del mantenimiento, según los requerimientos del CTE y la LOE. https://itec.es/programas/dicpla/ (15/03/2015).

[12] ITeC. Programa para la gestión técnica del mantenimiento preventivo y corrector de grandes patrimonios inmobiliarios. https://itec.es/programas/pgme/(15/03/2015).

[13] Marques, C., Ribeirinha, V. SIGMO – sistema informático de gestão de manutenção e operação". Jornadas FM, 2014. apfm.pt/imagens/Ap-Parque-Escolar.pdf (15/03/2015).

[14] Software Advice. http://www.softwareadvice.com/ (14/03/2017).

[15] Volk, R.; Stengel, J.; Schultmann, F.: "Building Information Modeling (BIM) for existing buildings – literature review and future needs", Automation in Construction, Vol. 38 (2014), pp. 109–127.

[16] Ilter, D.; Ergen, E., "BIM for building refurbishment and maintenance: status and research directions", Structural Survey, Vol. 33 Issue: 3 (2015), pp. 228–256.

[17] Falorca, J., Calejo, R., Mendes da Silva, R., Lean Building Maintenance – proposal for a conceptual approach. ICEUBI 2013 – International Conference on Engineering, Covilhã, Portugal, 2013.

[18] Falorca, J.; Calejo, R.; Mendes da Silva, R.: "Research measurement of knowledge advances in building maintenance issues". Structural Survey, Vol. 32 Issue: 1 (2014), pp.61-71.

Chapter 4

Conclusions

4.1. Framework

The main objective of the study developed in the scope of this thesis and presented in the previous chapters, was essentially to deepen the knowledge on the subject of BMM, formulating a scientifically sustained hypothesis in order to obtain a guideline model for procedures, aiming a more integrated management.

It was considered that the presentation of this subject, using published contributions, could be carried out here, in two stages, which matches with chapter 2 and chapter 3.

Thus, generically, it was firstly addressed organised measures for implementation of maintenance in some of the BE which need special attention throughout their useful life. For such, an earlier developed model was presented for a general inspection and maintenance plan, called PIMEC, tested in more detail on an ETICS. The aim of this work was to create an initial model, close to a manual, which would provide basic ideas for an adequate organisation of aspects related with the inspection and maintenance of a current building.

Hence, chapter 2 comprises two contributions. In section 2.1. an introductory literature review on various theoretical and correlational aspects in the field of BM and its management was presented. In section 2.2., it was addressed a proposal for a model of PIMEC, its test and validation, based on the inspection of a large area of façades of a number of buildings covered with ETICS.

Due to a wide knowledge gathering of this phase and a higher maturity achieved, in a second stage, guidelines were outlined for an information system which is intended to become real in terms of computer support. This aims to facilitate the operating performance of any organisation, regardless its size and kind of assets involved. This system, projected through an algorithm of procedures, was called SIAPME. Therefore, based on a coherent organisation approach, the intention was to establish a set of guiding principles or sustainable strategies which may can, in the future, enjoy a completely automated and simplifying procedures platform, through a base model of innovative design, more comprehensive and integrative of all information than many existing systems or programs.

Since SIAPME's development work has involved several phases, consequently making it longer, chapter 2 included five contributions. So, the first three are essentially seen as bibliographical reviews. Specifically, in section 3.1. a bibliometric study was carried out to evaluate the general progresses occurred in the knowledge of BM issues; section 3.2.

comprised a brief bibliographical review of several models, systems and methods used for MM; and section 3.3 presented a proposal for a conceptual approach on the application of the Lean concepts in GME. The basic principles and guidelines of SIAPME's model were then explained in section 3.4. At last, in section 3.5, it was described a computerised adaptation developed for one function of the model mentioned above.

4.2. Main results

Although the study presented in this thesis has somehow associated a strong theoretical component, it is thought that, in general terms, the results seem to be quite positive and useful.

Thus, the main results are described as follow.

4.2.1. A maintenance model to roughly estimate ETIC´s long term-behaviour

Through discussion of chapter 2, it seems relevant to mention some of the most important points:

- BM must be based on a logic approach to the planning of periodic intervention strategies (isolated or combined) and their administrative actions, applied over the useful life of BE, so that useful information is constantly produced, techniques are improved and scientific knowledge in this area is deepened;
- The importance of management actions on maintenance and durability of buildings was highlighted. Thus, in the particular case of building management, three perspectives must be taken. The first concerns the implementation of Technical Management, which covers all types of actions, aiming to ensure the performance of the constructive solutions, to correct functional deviations and to evaluate operating conditions (basically, it represents the majority of maintenance procedures). In a second perspective, it is necessary to perform the Economic Management, controlling, along the lifetime of buildings, the influence of deferred costs on the economic balance of investment made with it. Finally, it is necessary to ensure the Functional or Social Management of buildings, i.e. to promote the proper utilisation of buildings, in particular by defining rules and framing behaviours that meet the common needs of its users;
- The consideration of maintenance methodologies in the field of building management should be an integral part of all phases of an undertaking process, with the purpose of obtaining an integrated system with background information which may still be useful in future cases;
- With the establishment of a PIMEC process of actions, it is possible to make a selection and to characterise the main BE, collecting a set of meaningful information

concerning them. Also, with this model it is generically possible to increase knowledge regarding parameters involved in the simulation of different maintenance procedures, thus facilitating the presentation of simplified approaches, as well as to get a better understanding about the interaction between BE;

- Through testing maintenance planning according with different line of action foreseen by the PIMEC model, it was possible to validate maintenance strategies for ETICS (a modern type of coating), thus providing a general overview about what may be its long term-behaviour - it is believed to be quite promising in terms of durability, regardless the type of maintenance strategies advised. Obviously, the configuration presented for PIMEC was intended to be a debatable model, serving as a basis to find a better, more effective and modern solution.

4.2.2. An integrated and modern model of procedures for building maintenance management

Still based on a wide range of learned knowledge arising from PIMEC proposal, SIAPME was later developed. Thus, the consummation of this objective was based, first, on a set of bibliographic review stages.

With this work in particular, it was essentially intended to further deepen more knowledge on the subject of BMM and to formulate a scientifically based hypothesis.

4.2.2.1. Great growth expectations in the knowledge on building maintenance issues

Firstly, with bibliometric investigation, it was possible to evaluate in detail the progress which has taken place in the knowledge strands with interest for MM, to obtain an approximate growth model of the literature and, at the same time, to have some indications about possible gaps. It was thus an interesting and perhaps different contribution in the sense of characterizing the state of the art.

So, from section 3.1., further conclusions can be drawn:

- With respect to a hypothetical global model of evolution of available literature, the global survey of titles showed that in the late 1970s a phase of higher growth had begun, until the end of the 1990s, when the production of publications had risen to higher values significantly, remaining during the 2000s, with a relatively stable average in high. For example, it has been found that the period between 1999 and 2011 corresponds to about 67% of all publications identified. Also, in the case of Portuguese publications, the tendency has been for an apparent growth;
- It was also observed that the expressions with the highest incidence in the collected titles were 'maintenance management', 'building maintenance' and 'facilities management' and the first three groups of expressions included words like

'maintenance' (or 'repairs' and 'conservation') and' manage(ment)', representing almost two-thirds of the total number of such occurrences;

- Also, the group of expressions around subtopics related to computerised maintenance had an occurrence ratio of approximately 5%, which may well represent one of the various subjects which draws great attention in recent times, with potential to increase. In this way, it can be assumed that the guidance line of the academic study here exposed fits into a research field which seems to have certain priority as well as an opportunity which may hold some potential success of exploration.

4.2.2.2. Current maintenance management models and systems - the importance of a comprehensive review

A set of MM models and systems applied both in the industrial sector and in buildings were studied. Therefore, from section 3.2. it has been found that:

- Industrial maintenance is making use of techniques that are constantly changing due to a continuous investment in their development, many of which are already quite advanced. It was therefore considered that it might be advantageous to retain some knowledge in this field and possibly to apply it (as far as necessary adaptations and possibilities are concerned) - especially when studying ways of idealizing integrated maintenance models, easily applicable, irrespective of the size of buildings or of the set of buildings;
- For example, Terotechnology was the first set of MM practices which emphasised the importance of integrated equipment life cycle cost (LCC) analysis, thus aiming at minimising it. Its basic model intends to give designers feedback on the information generated in the different stages of the life cycle of an asset to be maintained;
- WCM has also affirmed itself as a strategic capacity for competition through integrated asset management. Its main objective is to achieve a high degree of competitiveness and enable companies to compete in any international market, using as main resources a CMMS, the operational improvement, RCM, TPM, CI, preventive and predictive maintenance and still following the six levels of evolution to the proactive maintenance;
- For its part, Benchmarking is one of the most important aspects to improve performance. It allows a comparison of best practices using the best companies, also enabling them to know the strengths and weaknesses of their processes, of new ideas and incorporate it;
- TPM aims to eliminate flaws, defects and other forms of losses and wastes, in the pursuit of the overall maximisation of efficiency as well as the involvement of all, at all levels.

From the general study of these methods, it is concluded that they are extremely important and cover many objectives and procedures which may be of great utility from the perspective of BM. That is to say, especially in terms of using their general concepts (if superficially viewed) or of detailed transposition of its techniques (if seen in a more incisive way) - in latter case, it may involve further study and investigation, so that this connection can be as perfect as possible.

Also, concerning in particular methods developed or already applicable to buildings, it was possible to draw some interesting conclusions.

For example, it is very common for FM and PAM to appear associated with BM.

With respect to FM, it can generally be referred to as being a professional activity of assets management and services, in order to support the activity of an organisation. It is a growing and still not widely disseminated discipline in Portugal in a structured manner, but with great growth potential compared to what has been seen in other countries. In general, literature refers that FM allows the management of four main resources of an organisation: financial resources, human resources, fixed assets (building patrimony and equipment) and resources related with information and knowledge. In addition, considering an organization's management divided into 3 distinct areas (strategic management, tactical management and operational management), FM could be applied to each of them, albeit with a different scope.

In PAM's case - the concept has been lately seen with a great deal of interest and development, and a set of specifications (PAS 55 standards) have emerged and allowed more appropriately to define the current Asset Management context and its application domain. In essence, the most current definition is closely linked to systematic and coordinated activities and practices through which an organisation manages assets (in a more optimised and sustainable way), its performance, risks and costs in order to fully satisfy its organisational strategic plan.

In addition to the detailed study of a BMMS's components, it was inferred that some very recent normative documents are increasingly being developed and made available, coming with excellent directives for planning, management and control of BM (particularly abroad). It has been found, for instance, that the QDHPW in Australia also has a number of very useful documents to guide the definition of new models and strategies for the management of maintenance activity.

Thus, generically, an MMS should follow the main lines: (i) maintenance planning and development; (ii) to include overall aspects intrinsic to maintenance accomplishment; and (iii) to consider computerised maintenance management systems (in generic terms).

A number of important performance indicators have also been developed by several entities and researchers, specifically directed to maintenance, normally used during the review of an MMS, as a way of verifying and evaluating its functioning. In an approach to situations of existing BMMS (or meanwhile developed), a few national and foreign cases were also analysed. It could be highlighted the management of building patrimony of University of Savoie in France, which according some relevant literature, is also based on a very broad range of activities, and whose line of action envisaged, seems to be quite interesting.

Despite differences in terms of detail, studied cases always have by master lines: a condition survey, the prioritisation, the maintenance planning, the budgeting and the accomplishment of work. It has also been verified that some of these methods have already introduced aspects of risk management and performance.

Although the survey of these examples of management of building patrimony have a theoretical background, a notion about their organisational structures may serve as a reference for other entities which also perform BMM and simultaneously, to serve as a guide for the development of applications which will allow a more effective control of information.

Finally, there is a wide range of methods related with AB'sC, resulting from good research, carried out both at national and international level, involving in many cases, in this matter, the public interest. In almost all developed methods, it was found that the respective scope is almost always common between them (usually directed for housing), as well as the visual inspection is normally the method used for condition assessment.

All in all, there is already a great diversity of applications and studies of great interest for BMM. There is also a growing emergence of very appropriate and demanding policies for the implementation of BMMS (particularly those developed in the Anglo-Saxon and Francophone domains), some high-quality normative guidelines and a number of good academic research works.

4.2.2.3. The Lean concept as a roadmap for a culture of continuous improvement

From the study of Lean concept (section 3.3.), it can be concluded that the principles of Lean Thinking represent a roadmap for its implementation in organisations (including those particularly directed to BM), mainly in order to introduce a culture of CI. Therefore, in a Lean organisation, everyone must be single-minded to identify and suppress sources of waste and inefficiencies.

From what was considered to be a BMMP - in which it is hypothetically assumed that all resources are integrated and centralised, e.g. in a computer system - a set of possible interactions between the various agents involved was designed. And considering the causes of waste which may occur in the utilisation and maintenance phases, the baselines for the

respective integration of the Lean principles were created, judging then launching a set of new ideas around Lean Thinking. Thus, it was decided to simply call it as LBM. The main objective was essentially focused on a need to stimulate the streamlining of procedures.

It has also been possible to note that there were some interesting developments in the Lean Maintenance and LC topics, whose fundamentals may also contribute to the development of new theories or applications.

4.2.2.4. Reaching SIAPME - a well-founded guidance tool for building maintenance management

From a somewhat more up-to-date review, it was also concluded that when considering new challenges in contextualisation, it can be as well highlighted the importance of aspects concerning with technological applications to support MM. For instance, it has been noted that for two decades there has been great progress and improvement in ICTs, adapted to FM and/or to BMM. As far as its coverage in what a BE is concerned, applications which allow flexible use and based on scientifically tested models or supports are still lacking; although abroad, there is already a broader set of solutions for MM of infrastructures, but many of them still show certain limitations in this particular. Also, the introduction of computers and custom software has substantially improved the ability of facility managers to fulfil maintenance aspects such as the systematic collection, monitoring and measurement of data and strategic decision-making, in relation to the required level of maintenance.

It was also concluded that two most well-known types of FM or BM software are CAFM and CMMS. In general, these types of software support FM activities with applications for asset management, MM, real estate portfolio management, space management, environmental sustainability, etc.

Therefore, without an effective information system it may not be entirely possible for building and facilities managers to ensure complete maintenance. Information control is one of the increasingly important aspects in modern societies, and so any maintenance organisation should not waive to use the most appropriate means for its collection, storage, processing, representation and distribution, thus minimizing the effort required by such concerns. This implies that the use of information systems for BMM is an important issue to take into account.

In case of BIM, there is now a major discussion due to the assumption that BIM information collected during the life cycle of a facility could help to improve the management efficiency of the asset in question. That is, it seems that, being a rapidly developing technology, BIM presents potential in problem solving at all stages, including O&M. The bibliographic review carried out in this field also allowed to verify that the topic BIM in FM has become an important subject under study.

It was possible to verify that the use of BIM in the O&M phase of buildings could bring advantages, have limitations and some associated challenges. Regarding the advantages, the integration of BMM into BIM supports may eventually increase the efficiency of the maintenance process, but as regards data transfer of between BIM models and building and FM systems, the process may not be direct or economic. The lack of interoperability between software systems may be one of the limitations that explains why BIM's potential in the O&M phases of buildings has not yet been fully utilised. Therefore, current challenges are mainly based on the need for best practices to develop data transfer strategies.

With the treatment and assimilation of previously knowledge, a set of guidelines for a so-called SIAPME was devised (section 3.4.). Thus, from this study it is possible to conclude that:

- Information systems directed to MM should have as a functional basis the interaction between the main sectors of activities, i.e. General Management; the patrimony itself (physical components); Outsourcing, which includes all external services; and Interaction, to make the User(s) participate in (and inherently also the User(s) of the system itself) - which basically are all entities mentioned above. In the interaction between General Management, Patrimony and the system itself, an Organisation can be found as a joint basis;
- It is imperative to exist the figure of a General Manager, who informs and interacts with top management or with the Organisation and coordinates all sectors of activity and their stakeholders. Therefore, this is a very broad work function for which the person should be properly prepared for;
- The role of General Manager should always be based on a number of guidelines, as well as to have good perception of different management levels. Thus, he should perform a top-class management, keeping in mind a cycle of CI, performing periodic Benchmarking tasks, taking into account Lean practices and working with the goal of having sustainable facilities;
- The General Asset Management Functions (GAMF) should always cover control of all activities: the management of Support Resources and of real estate; the Operational Maintenance; the numerous features of patrimony ‘Exploration’; and ‘Update and Valuing’ the same.

Therefore, it is possible to say that after an eventual process of adaptation of SIAPME in a definitive software solution, this may have cross-cutting characteristics to those considered in CAFM and CMMS systems classifications, covering even more than the usual range of its modules.

In addition, a software solution, with a base algorithm inspired in SIAPME, will also cover a wide range of additional aspects which generally are not taken into account in most existing or marketed systems and programs.

It was also envisaged that a real tool, further coming from the model outlined, may jointly use of a wide range of advanced technologies to support its functions, such as Cloud Computing, Intelligent Telemetry Systems, Automation and Domotics, Wireless Communication Systems, Geographic Information Systems (GIS), Barcodes, etc.

4.2.2.5. Testing partially SIAPME - achievement of a well succeeded experimental computerised adaptation

The test accomplished with the experimental computerised adaptation of SIAPME (section 3.5.) already attempted to confirm a few aspects of the above-mentioned conclusions. That is, it seems to have been demonstrated that both the work defined for BM, as the one that is due to its control of activity, will only be extremely efficient if, in this particular, the management of Support Resources as a whole, is carried out on the basis of a very well organised system, providing correct information about all stakeholders and about all components.

The developed computerised adaptation is quite versatile, intuitive, dynamic, showing a simple configuration, and at the same time already fairly comprehensive in terms of covered management areas. Such characteristics seem to be the groundwork for an eventual success of a future software solution which best fits to the entire operational spectrum of SIAPME algorithm.

4.3. Objectives assessment

Overall, it is considered that the objectives intended to be achieved with this study were entirely met.

The general guidelines for an information system which seems clearly able to become real in terms of a computer application and contribute to the functional performance of any organisation, regardless of their size and the type of assets in question, were presented.

The basis of the planned model (SIAPME) seems to have a coherent organisation, an innovative character and to enable a vast coverage and great integration of all information needed to be managed. So, it is believed that in this particular, the work performed and here described, can contribute to the dissemination and usefulness of theme, fundamentally due to its extent and originality.

By reading the different points of this study, it is also clear that: first, it achieves the objective to raise awareness to various stakeholders in construction process as well as the asset managers on the need to plan maintenance and to conduct its best management, specifically by making use of appropriate IT tools; second, to draw attention to the consequent favourable short-term impact, and to the undoubted long-term benefits, related with the practical achievement of multiple aspects highlighted here.

The bibliometric study carried out, also makes it possible to get a national and international perspective of the approximate growth model of literature, in particular with interest for BMM.

Also of great importance are illations learned from research on current issues, which go beyond those intrinsic and conventional to maintenance, such as: the increasing use of ICTs, aspects related with the sustainability in the built environment, comfort, energy efficiency and the use of renewable energies and resources, etc., all this in the sense that, in a very short term, they will also deserve integrated treatment.

It is believed that a perspective about all essential and intrinsic aspects related with technological applications for supporting BMM (and their importance in this context), has also been conveyed effectively and clearly.

Moreover, to fully achieve the objectives pursued by the accomplishment of SIAPME model, it was quite fruitful to research the main management aspects used in the field of industrial maintenance, which, as they have been exposed, will always be of great interest for a more incisive and timely integration in the field of BM.

The computerised adaptation testing is an empiric basis which shows, on the one hand, that the algorithm of procedures foreseen by SIAPME has a logical framework, and on the other hand, consequently, that there is a perfect adaptability of its ideas for a computer program (software), which may be deeply worked afterwards.

It looks that studies and projects to be developed, with similar nature of those presented in this thesis, as well as projects of improvement and/or of updating of computer tools essentially geared to BMM, might find in this work many useful and well-founded aspects, in sense of helping them at those ends.

4.4. Difficulties

The accomplishment of a work of this nature and amplitude always entails some associated difficulties. The most relevant was related with yet some scarcity, in Portugal, of specific bibliography on this subject, despite some literature already developed in recent years. In fact, the weak culture focused on aspects of BM may be reflection of this. Therefore, this study has largely considered foreign literature.

The bibliometric study presented in chapter 3 (section 3.1.) also had certain associated limitations, which have been described in with more detail. In addition, it is noteworthy that this research was restricted to 2011, since it was not yet possible to update it, nevertheless results may still be considered fairly valid. Efforts are being undertaken in order to joint recent data, envisaging an eventual upcoming actualisation.

Also, research carried out within Lean philosophy was developed under some limitations, such as the existence of a certain dispersion related with the use of aspects of Lean knowledge as well as some lack of literature covering studies in the BM phase. On the other hand, the embryonic nature of work developed does not allow an answer to other more detailed questions for the time being, since the research was largely limited to a literature review, which lacks validation from more and better empirical evidence.

As it was already been given to understand, concerning the algorithm of procedures (SIAPME), it was not yet possible to adapt it into a more robust computer program (i.e. to develop a software which could covers the entire model). The main reason is that its achievement still implies a long period of time in order to adapt all functions envisaged - perhaps two or more years of team programming, with the participation of human resources specialised in computer science. Which signifies that it would be necessary to find favourable conditions for the eventual accomplishment of this big project. Nevertheless, it has already been possible to carry out a test on the proposed model, even partially, by means of an individual study work, making use of own resources, as it was described in section 3.5.

Anyway, the major challenge of this research was to achieve the main objective outlined, despite some poor resources and the conditions involved. But the difficulties were overcome and the end result seems to have clearly exceeded expectations, invalidated any initial scepticism.

4.5. Some notes about future developments

Although this thesis is a simple contribution aiming at greater sensibilisation as to some change of attitude regarding for adequate practices in the whole management of buildings, and considering a certain diversity of 'sub-issues' within this specific theme, it is however, regarded as essential the development of further (different) approaches.

Thus, there are other aspects which may be also further explored, helping to improve BMM's activity:

- To proceed with more research development, mainly based on behavioural tests, targeting materials in general and the different sort of coatings in particular, in order to establish a scientifically substantiated database on the useful life of the different BE (perhaps the most commonly used);
- To develop methodologies tailored to each case, in the sense of being possible a deeper analysis of degradation mode of BE, such as type of inspections, techniques to be used, more recent inspection techniques, etc.;
- To develop a scientifically-based database of intervention sheets, highlighting the importance of the most important details which can ensure appropriate durability of

BE. In the following, to proceed with databases establishment on costs of operations in accordance with own techniques;

- Concerning ETICS application on buildings, it seems important to maintain an analysis work about its in-service behaviour aiming to further deepen the knowledge about this type of coating system and eventually rectify any procedures, or less accurate conclusions derived from the test of PIMEC.

Taking advantage of the line of thought which was established along this thesis, from which was carried out a proposal of general lines for an information system for automatisation of procedures in BM, it is believed that future research works could be exactly focused on the analysis of further and occasional improvements (eventually necessary). Thenceforth, it should be proceeded with its adaptation into a complete software, as well as with the performing of the necessary adjustment tests.

Obviously, coming from the multiplicity of studied aspects, there are some which will continue to deserve greater attention, such as the need for further investigation about application of Lean principles into the utilisation and maintenance phase of buildings.

In addition, it is thought that further studies are needed on how to exploit and transpose into buildings, the most successful methods and techniques of MM, used in the industrial sector.

Finally, it is also important to extend the study of performance indicators to the physical behaviour of buildings, to deepening the introduction of risk analysis methodologies in MM and to promote the development of strategic plans adapted to organisations.