XII DBMC
International Conference on Durability of Building Materials and Components
PORTO - PORTUGAL, April 12th-15th, 2011

Planned Preventive Maintenance Activities: Analysis of Guidance Documents

Sónia Raposo [1]
Manuel Fonseca [2]
Jorge de Brito [3]

ABSTRACT

In Portugal there is, traditionally, a greater concern with the design and construction development phases than with the operating and maintenance phases. The lack of preventive and planned activities throughout the years and the systematic postponement in the execution of works due to financial constraints has led to a profound and widespread degradation of Lisbon elementary public schools.

A research study is being carried out aiming at the definition and implementation of sustainable maintenance practices by the Lisbon Municipal County. Based on a comprehensive survey of published literature and reports on international case studies, a performance maintenance management model was developed on the basis of this study, which allows for an evaluation and a sustainable intervention in the Lisbon elementary public schools built park.

The planned preventive maintenance activities and the statutory planned preventive activities in five school facilities were established through international references and consultation of national regulations and the opinion of Portuguese construction product manufacturers.

This paper presents a critical analysis of four guidance documents, intended to provide facility managers with planned preventive activities and related costs. The analysis revealed that these documents do not equally address all the construction elements, systems and equipments and outer spaces. The discrepancies between documents are discussed, and also the need to modify and adapt these guidance documents to better address the requirements of Portuguese facility managers.

KEYWORDS

Planned maintenance, Guidance documents, Maintenance management, Elementary public schools.

[1] National Laboratory of Civil Engineering (LNEC), Buildings Department, PORTUGAL, sraposo@lnec.pt
[2] National Laboratory of Civil Engineering (LNEC), Buildings Department, PORTUGAL, mfonseca@lnec.pt
[3] Instituto Superior Técnico (IST), Civil Engineering and Architecture Department, PORTUGAL, jb@civil.ist.utl.pt

1 INTRODUCTION

Today the management of public built assets gains a significant importance owing to their size, social relevance and the corresponding working, operational and maintenance costs. Since it is economically relevant to the total cost of a building, the activity of maintenance management cannot be done in an improvised and casual way. Currently, initiatives undertaken in this field aim at a sustainable development, or seek to rationalize and optimize the available resources through the implementation of integrated and cost-effective solutions, allowing an acceptable performance of buildings along its life cycle as well as its services [OGC 2003, Cooper 2008].

Based on a comprehensive survey of published literature and international case studies reports, an objective and flexible methodology for measuring and evaluating the performance of the building stock a Maintenance Management Systems (MMS) was developed and tested in a sample of five primary schools in Lisbon. The study presents an analysis tool that integrates key performance indicators on technical, economic and organizational aspects (Figure 1).

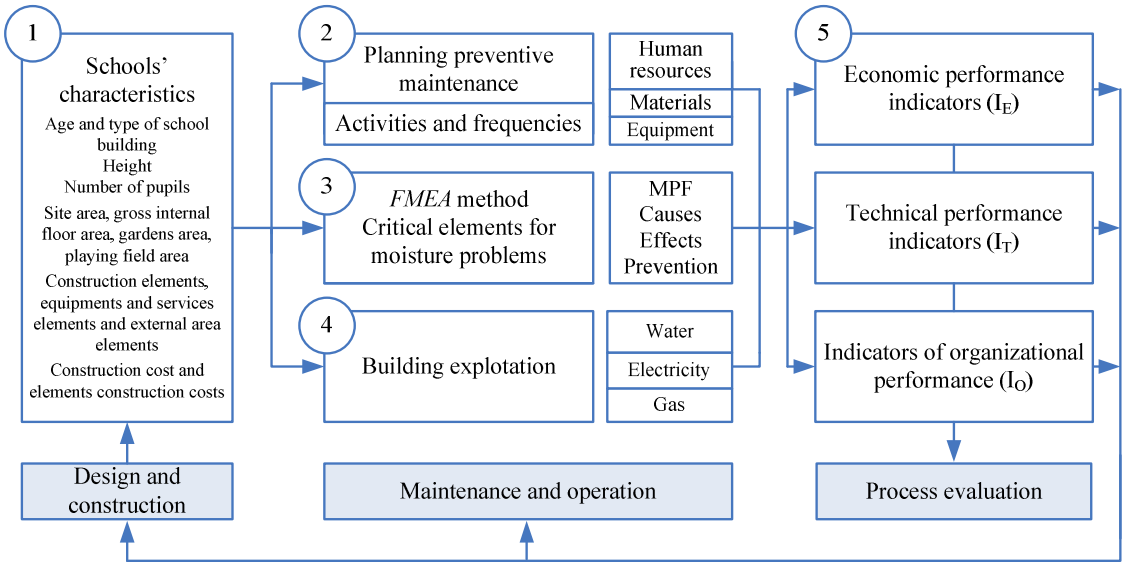


Figure 1. Methodology for measuring and evaluating the performance of the building stock Maintenance Management Systems. [Raposo 2010]

The planned preventive maintenance activities and the statutory planned preventive activities were established through international references and national regulations consultation and national manufacturers' opinion. Four databases, containing information about maintenance activities were consulted: a French source "*La maintenance des bâtiments en 250 fiches pratiques*" [Albano 2005], a Spanish source "*Fitxes rehabilitació of ITeC*" [ITeC 1991], an English source "*Housing component life manual*" [HAPM 2003] and a North American source "*The Whitestone facility maintenance and repair cost reference 2009-2010*" [Abate *et al.* 2009].

2 GUIDANCE DOCUMENTS INFORMATION

The French book "*La maintenance des bâtiments en 250 fiches pratiques*" [Albano 2005] presents maintenance activities for 9 major groups of building elements: structure, exterior envelope, roofing and waterproofing, interior construction, plumbing, HVAC, electrical equipments components, other electrical installations, basements and other services and external works and landscaping. Each sheet presents the maintenance activities, frequencies and maintenance ratios, broken down in five levels: inspection, cleaning and preventive maintenance, light intervention, heavy intervention and replacement. Lastly, the maintenance activities covered by specific legislation, such as fire protection or electrical installations are presented, allowing a comparison of the French and Portuguese

legislation in these areas. This source was chosen as a basis for the study, as it presents recent information (i.e. published in 2005) from a country with a significant number of similarities in terms of building construction techniques.

The document "*Fitxes rehabilitació of IteC*" is made available online by the Institut de Tecnologia de la Construcció de Catalunya website [ITeC 1991] and is divided into three volumes: building maintenance, services maintenance and urban spaces maintenance. Even though it is an old document, its geographical proximity to Portugal and the use of similar building technologies led to the data available being also analysed.

The building is divided into exterior elements, roof covering elements and exterior finishes, windows and doors, and interior elements, covering the finishes, the interior doors and the sanitary and kitchen equipments. The volume related to facilities includes: smoke evacuation installations, ventilation and waste disposal facilities, HVAC, kitchen facilities, water supply and sewer facilities, valves, pumps and pressure groups, electric and lighting systems, transportation facilities, fire protection facilities and installations of audio and video. The volume of urban areas includes: fences and gates, paving elements, equipments, services and landscaping.

For each element, the sheets contain a list of the most common anomalies, the maintenance activities and frequencies and their service life (except for services installations). The Spanish document presents three maintenance levels, high (A), medium (M) and low (B), according to specific environmental exposure or use factors.

In the "*Housing component life manual.*" [HAPM 2003], the information is structured into the seven following groups of components: floor components, wall and cladding components, roof components, doors, windows and ironmongery, mechanical equipment components, electrical equipment components and external works. In general, each group is divided into types and sub-types that are assigned a score corresponding to one of the following classes: A = 35+ years, B = 35 years, C = 30 years, D = 25 years, E = 20 years, F = 15 years, G = 10 years, and H up to 5 years.

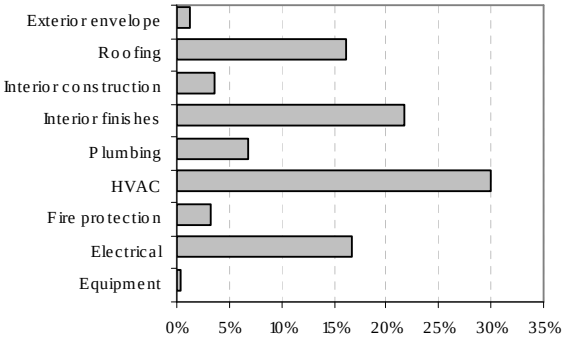
The "*Whitestone Facility Maintenance and Repair Cost Reference 2009-2010*" reference [Abate *et al.* 2009] provides maintenance and repair costs from various sources of information and various types of North American establishments. This reference represents the result of 14 years of continual work from the Whitestone Research Company with several US government agencies and consulting firms that work in this area. This collaboration yielded the information needed to calculate the cost of maintaining a building over its service life, the amount and type of resources associated with this maintenance and the lifespan of the various constituents of the building.

The document uses the North American classification system UNIFORMAT II (classification of asset elements), published by *ASTM - American Society of Testing and Materials* [ASTM E1557 2009], which includes the following items: substructure (foundation and basement construction), shell (super structure, exterior envelope and roofing), interiors (interior construction, stairs and interior finishes), services (lift, plumbing, HVAC, fire protection and electrical) and equipment and furnishings.

The data presented refer to maintenance and repair activities (M&R) and are divided into: preventive maintenance (PM), unscheduled maintenance (UM) and replacement (R). PM and minor repair consists on scheduled tasks that sustain a component's level of service during a prescribed service life. The UM consists of service calls, emergency response, and other tasks that cannot be individually anticipated and replacement consists of component overhaul or major replacement tasks. These tasks extend a component's service life, and reset the schedule of PM and minor repair tasks. Activities related to facilities operation, such as landscape maintenance, are not included in this book.

The book features 72 maintenance profiles for various types of facilities and equipment, for a study period of 50 years, with the costs of maintenance and repair, per m^2 of building area and as a percentage of replacement value. An example of a maintenance profile of a North American primary school is given in Figure 2; the school, of 3.7 m height, has a gross internal floor area of 4360 m^2, built of reinforced concrete, screed, carpet and vinyl floor tiles and ceilings with plaster finish. The building has a replacement cost of 7251764 € [Abate *et al*. 2009].

Distribution of M & R costs



50-year M & R cost summary

Task type	50 year total cost	Annual cost per gross internal floor area	Annual cost as % of replacement
PM & minor repair	1044770 €	0.44 €	0.29%
Unscheduled maintenance	805085 €	0.35 €	0.22%
Renewal & replacement	4114134 €	1.75 €	1.13%
Total	**5963990 €**	**2.53 €**	**1.63%**

Figure 2. Maintenance and replacement cost profile for an elementary school. [Abate *et al.* 2009]

In the current study, information on preventive maintenance activities was collected, including routine inspections (I), maintenance and cleaning routine (M), and component replacement (S). In Table 1 a summary of the collected data and the main application fields of the model to measure and evaluate the performance of the building stock Maintenance Management Systems (MMS) are presented.

Table 1. Type of data available in the references listed and application fields in the research study.

Type of information available	*Whitestone 2009*	*Albano 2005*	*HAPM 2003*	*ITeC 1999*	*Scope*
Service life	Yes	Yes	Yes	Yes	I_T
Factors influencing the service life	No	No	Yes	Yes	Sensitivity analysis
Description of maintenance activities and their periodicity	Yes	Yes	Yes	Yes	I_T
Factors that influence the maintenance activity	Yes	Yes	No	No	Sensitivity analysis
Human resources and labour hours per maintenance activity	Yes	No	No	No	I_O
Data to calculate the maintenance activity cost	Yes	No	No	No	I_E
Most frequent anomalies in components and building system	No	No	No	Yes	Failure modes *FMEA* (I_T)

3 RESULTS AND DISCUSSION

In the five schools studied the exterior envelope is made of double walls with hollow ceramic brick masonry and thermal insulation and exterior openings with anodized aluminium frame and colourless single-pane glass (colourless double-paned glass in Alto da Faia school) (Figure 3). The walls should be subject to regular inspections every three years and the windows and doors every six months. The condition state of the finishing of the frame, operation and state-setting mechanisms for openings and fittings, condition of gaskets and mastics and verification of clearance at outlets for water flow should be followed [Albano 2005].

Figure 3. View of school São Bartolomeu (left); Posterior view of Alto da Faia school (centre); South view of Alto da Faia (right).

Preventive maintenance of the exterior walls consists in their cleaning and eventual closing of cracks and joints, whenever the conservation status of the walls requires or once every 10 years [Abate *et al.* 2009]. The exterior walls service life exceeds 50 years of the research study, and according to Abate *et al.* [2009] it exceeds 75 years, whereas Albano [2005] does not mention any period. The outer openings require a yearly maintenance of hardware replacement, lubrication of door locks and joint replacement. The replacement of windows and doors is indicated every 25 years in Albano [2005], with replacement of mastics to occur between 10 and 15 and the fittings around 15 years. The HAPM reference [2003] and Abate *et al.* [2009] differ in terms of the service life of window elements, offering 35 and 75 years respectively, and the service life of exterior doors, 30 and 50 years respectively.

Roofs are predominantly of sheet steel and reversed flat roof types. The former must be annually inspected, performing at the same time preventive maintenance activities, such as cleaning the surface and checking the tightness of fasteners; unclogging the rainwater plumbing and checking the proximity of tree branches. For the latter, inspections should be carried out every six months with maintenance activities to be held annually. The metal roof's service life is 25 years [Albano 2005], whereas ITeC [1991] makes a distinction between the roof metal covering's service life (30 years) and the support structure repair (50 years). The service life of flat roofs depends primarily on the conservation status of the layers of support, thermal insulation and waterproofing; Albano [2005] suggests every 20 years.

Skylights should be inspected annually by verifying the conservation status of the window frames, glass, gaskets condition and mechanisms for opening and closing the windows. Maintenance activities, to be held twice a year, consist of cleaning, lubrication and adjustment of all moving parts. The rain water drainage system should be inspected and cleaned every six months, checking the condition of connections and pipes and all system performance, namely the water flow. Albano [2005] refers the entire system replacement after 15 years, whereas Abate *et al.* [2009] mentions the need to replace up to 20% of pipe after 30 years and total replacement after 40 years.

The interior walls are in general made of single pane perforated ceramic brick masonry (in thicknesses ranging 0.20 m to 0.35 m) and should be subjected to regular inspections every three years verifying the opening of cracks, deformations or moisture stains presence. The replacement of these elements occurs every 30 years [Albano, 2005]. Ceilings in gypsum board are an uncommon solution in school buildings, appearing occasionally in recent schools in circulation areas or in the lobbies of entrances to the classrooms. Annually one should proceed to a visual inspection/maintenance, to check the aspect and its attachment to the support structure. Replacement occurs after 20 years, during which one should be aware of its possible deformation or the existence of water originating from the underlying services.

The interior openings are mostly in wood finish, with sliding doors in the separation between the classrooms and areas of artistic expression. Control inspections should be performed annually, in

general verifying all moving elements. Maintenance should be held biannually with the lubrication and adjustment of the moving parts and hardware. The service life of the doors was considered to be in general 20 years and that of sliding doors 15 years.

The exterior cladding of the facades' schools is predominantly painted plaster. The control inspections should take place every three years, checking the general appearance of walls, in particular the aspect of painting and the existence of cracks and spots [Albano 2005]. The current maintenance activities include cleaning stains and dirt in localized areas. ITeC [1991] refers a periodicity of 15 years for repainting walls and ceilings and at 40 years a more in depth intervention on the plaster must be performed before repainting.

In external walls, ceramic tiles, varnished concrete and wood panels are used less frequently. In ceramic tiles the superficial appearance of walls, joints and the flatness of the surfaces should be checked. The main maintenance activity consists on cleaning surface dirt and efflorescence stains. The replacement of this type of coating is usually not considered. Walls in exposed varnished concrete require regular monitoring at 10 years intervals, to determine the need for surface treatment with waterproofing products, and cleaning maintenance every 20 years. Normally their replacement is not considered [ITeC 1999]. Wood panelling demands an annual monitoring inspection to check the surface of condition the panels, the performance of the support elements and the integrity of joints. It should be cleaned periodically [ITeC 1999]. Replacement of the support elements occurs around 40 years.

The flooring currently adopted for the classrooms is linoleum (in the older schools ceramic or wood can be found). The inspection of the linoleum flooring is to be done annually (every three years according to ITeC) focusing on the verification of the pavement condition in current areas (flatness) and localized areas (fixation and mechanical performance). Flooring requires periodic cleaning and its service life varies from 10 [Albano 2005], 18 [2009 Whitestone] to 20 years [ITeC 1999].

Wood flooring is a solution currently adopted for administrative areas and the monitoring inspection should be held annually, noting the state of conservation of surfaces and signs of moisture. The application of suitable surface products such as varnishes or wax is part of cleaning and routine maintenance. The referred service life of this pavement is 40 years [Albano 2005, Abate *et al.* 2009]. The floor finishing used in wet areas is ceramic tiles that have a service life of 50 years [ITeC 1999, Whitestone 2009]. It is a type of floor finishing that does not require great frequency of inspection but must be subjected to a weekly cleaning with products suited to its surface.

The most common coating for walls and ceilings is painted plaster. There should be an inspection every year to verify the existence of cracks or other damage and the adherence condition to the support. For paint coating, the surface appearance must be verified and as well, the presence of moisture, dirt stains or detachment of material verified. Washing the surfaces is the appropriate maintenance procedure to be carried out once every 3 years. Repainting should occur every 15 years, including the repair of the support. In wet areas and in circulation areas, ceramic wall coating is used requiring an annual inspection control of the surface aspect of the wall and cleaning of surface dirt and efflorescence stains, where necessary.

In Table 2 a summary (extract) is presented of the information collected on different elements preventive maintenance activities and frequencies and their impact in the number of intervention in building (technical performance indicator). The Albano [2005] source was chosen as a basis for the study and the Whitestone-W [2009], ITeC-I [1999] and HAPM-H [2003] sources were used to assess the former information.

4 CONCLUSIONS

The work presented resulted from the need to investigate the content of information sources in the area of preventive maintenance planning activities and the potential for its practical implementation. Currently the information on maintenance activities in Portugal is still scattered in different study areas that relate to building elements and components and in the various government agencies that manage building parks.

Table 2. Summary of information on preventive maintenance (extract). [Raposo 2010]

Element	*I*	*M*	*S (years)*	*Number of intervention (50 years)*
Exterior envelope				
Exterior walls	3 y	10 y (W)	NC	I=16; M=5; S=0
Windows	6 m	1 y	25; 35 (H); 75 (W)	I=100; M=50; S=2; 1(H); 0(W)
	1-4 y (I)	1 y (I)	50 (I)	I=50/12; M=50; S=1 (I)
Doors	6 m	1 y	25; 30 (H); 50 (W)	I=100; M=50; S=1(H); 1 (W)
	1-4 y (I)	1 y (I)	50 (I)	I=50/12; M=50; S=1 (I)
Mastics	-	-	10/15	S=5/3
Joinery	-	-	15	S=3
Joint	-	-	10	S=5
Roofing				
Metal roofing	1 y	1 y (I;H)	25; 30 (I); 40 (W)	I=50; M=50; S=2; 1(I;W)
Flat roof	6 m	1 y (A;I)	20	I=100; M=50; S=2
	5 y (W)	1 y (W)	35 (W)	I=10; M=100; S=1 (W)
Skylights	1 y	6 m	20/30; 40(W)	I=100; M=100; S=2/1; 1 (W)
Rain water drainage	6 m	6 m	15; 40(W)	I=100; M=100; S=3; 1 (W)
Interior construction				
Walls	3 y	10 y (W)	30	I=16; M=5; S=1
Gypsum board	1 y	2 y	20	I=50; M=25; S=2
Interior doors	1 y	2 y	20; 50 (I); 40 (W)	I=50; M=100; S=2; 1 (I;W)
Ironmongery	-	5 y	10 (W)	M=10; S=10 (W)
Sliding interior doors	1 y	2 y	15; 40 (W)	I=50; M=25; S=3; 1 (W)
Finishes				
Painted wall render	3 y	3 y	15 (A,I); 10 (W)	I=16; M=16; S=3; 5 (W)
Ceramic wall cladding	1 y; 5 (I)	20 y (I)	NC	I=50; 10(I); M=2; S=0
Concrete	10 y (I)	20 y (I)	NC (I); 75 (W)	I=5; M=2; S=0 (I,W)
Wood panelling	1 y	-	30 (I)	I=16; M= -; S=1 (I)
Linoleum flooring	1 y	-	10; 18 (w)	I=50; M= -; S=5; 2 (W)
	3 y (I)	-	20 (I)	I=16; M= -; S=2
Wood parquet flooring	1 y	2-5 y	40 (A; W)	I=50; M=25/10; S=1 (A;W)
Electrical				
Fluorescent lighting fixture	1 y	1 y	8-10; 20 (W)	I=50; M=50; S=6/5; 2 (W)
Fire protection	1 y (A;I)	2 y; 6m	20	I=50; M=25/100 (I); S=1
Fire doors	-	1y (W)	40 (W)	I= -; M=50; S=1 (W)
	1 y (*)	1 y (*)	20/30 (*)	I=50; M=50; S=2/1
Fire extinguisher	-	5y (W)	12 (W)	I= -; M=10; S=4 (W)

(*)Portuguese legislation

In this study it was found that the major maintenance costs that are incurred over the 50 years of a building's service life results from the renewal and replacement of components and elements at the end of their service life. This information is not always coincident in the different consulted sources and can considerably change the results of a life cycle cost analysis. The use of a standardized reference data for the presentation of maintenance costs (e.g. UNOFORMAT II or others) is important step to enable carrying out benchmarking actions. For instance, in *Whitestone*, the North American reference, [Abate *et al.* 2009] the item on wall external finishes is included in the exterior envelope, whereas in Portugal this item would be classified in coatings and finishes (both internal and

external).

In some regulated areas, such as the electrical equipment components or gas installations, Portuguese legislation is unclear on the type of maintenance activities nor their frequency of application. Lifts, fire protection and HVAC systems are subject to specific regulations, recently published, which require the existence of user manuals and maintenance plans.

REFERENCES

Abate, D., Towers, M., Dotz, R. & Romani, L. 2009, *The Whitestone facility maintenance and repair cost reference 2009-2010.* 14th Ed. Whitestone Research, California, USA.

Albano, Jean-René 2005, *La maintenance des bâtiments en 250 fiches pratiques*, Editions Le Moniteur, Paris.

ASTM E1557 - 09, "Standard classification for building elements and related sitework - UNIFORMAT II". American Standard of Testing Materials, Philadelphia, USA.

HAPM 2003, *Component life manual*, E&FN SPON, CD.

Institut de Tecnologia de la Construcció de Catalunya 1991[a], *Manteniment de l'edifici. Manteniment installacions. Manteniment urbanització Fitxes*, Barcelona. http://www.itec.es. Last accessed: 29.10.2010.

Cooper, J. & Jones, K. 2008, *Routine maintenance and sustainability of existing social housing*, CIB W070 Conference in Facilities Management, Edinburgh. pp. 361-368.

Office of Government Commerce (OGC) 2003, *Achieving excellence in construction. Guide 7: Whole-life costing* *http://www.ogc.gov.uk/ppm_documents_construction.asp*. Last accessed: 29.10.2010.

Raposo, S., Fonseca, M. & de Brito, J. 2008, *Survey of the state of degradation of the school buildings of the Lisbon region*, 11 DBMC International Conference on Durability of Building Materials and Components, Istanbul, Turkey, pp. 1081-1088.

Raposo, S. 2011, *The management of maintenance activity in public buildings. Model and strategies for a sustainable intervention.* PhD thesis, Instituto Superior Técnico (IST), Technical University of Lisbon, Portugal.