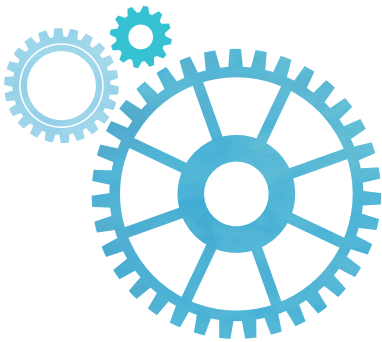


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Maintenance conceptual models and their relevance in the development of maintenance auditing tools for school buildings' assets – an overview

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Abstract

Despite the importance of building and infrastructure maintenance and its role in cost control, savings in materials and life cycle enlargement of equipment and facilities, maintenance is often still regarded only as a disturbing factor which causes Public school infrastructures to often suffer from the negative effects of this philosophy.

It is important for managers to improve maintenance performance of school organizations, focusing on areas such as maintenance, building systems, safety improvements and technology, if possible anticipating problems and opportunities in time. To accomplish all of those goals, these organizations must be determined to manage their available resources effectively and to seek improvements for increasing efficiency.

In this context, and with the aim of characterizing the Portuguese situation concerning the age and preservation of both installations and fixed equipment of Educational Institutions, as well as their maintenance strategies and politics, maintenance auditing tools for school building assets were developed.

This paper presents an overview of maintenance conceptual models as well as a proposal for a maintenance conceptual model aimed at the Portuguese Educational Institutions.

The full version of this paper discusses the relevant role of maintenance conceptual models in the development of maintenance auditing tools and contains some results of a study regarding the Portuguese Educational Buildings.

Keywords — *Maintenance management; Educational organizations, Maintenance strategies in asset management; Maintenance modelling and optimization; Maintenance audits.*

I. INTRODUCTION

The resources dedicated to maintenance and operation of school building infrastructures come mainly from the state budget. Since education is one of the sectors that most absorb resources, it is becoming more and more important to improve its efficiency [1, 2]. In fact, financial constraints usually result

in reduced maintenance and operation budgets and Public schools' infrastructures often suffer from the negative effects of this philosophy, presenting in some cases early signs of disrepair and neglect generally as the result of the priority on allocating funds to items that directly affect education [3].

Equipment that is in poor condition may interfere not only directly in the economics of the organizations, but also in the reduction of the overall availability of buildings while simultaneously interfering with the occupants' safety. This is why both installations and equipment associated with the operation of school organizations must be kept in good conditions [3,4].

It is important for managers to improve maintenance performance of educational facilities, focusing on areas such as maintenance, building systems, safety improvements and technology, if possible anticipating problems and opportunities in time. To accomplish all of these goals, educational and teaching organizations must be determined to manage their available resources effectively, and to seek improvements for increased efficiency. At the same time it's vital that they implement a regularly scheduled detailed maintenance plan for all assets [5].

In this context, a study was developed regarding the Portuguese Educational Institutions' maintenance management and organization. This paper contains some results of the study mentioned above. It identifies some areas needing improvements, as well as the suggestions made to improve maintenance efficiency, regarding management decision making and strategies employed in maintenance management.

With the aim of characterizing the Portuguese situation concerning the age and preservation of both installations and fixed equipment of Educational Institutions, human and material resources management, as well as their maintenance strategies and politics, maintenance auditing tools for school buildings assets were developed, with the purpose of collecting all the aforementioned information. Some results of the analysis carried out to the gathered global data are described. In addition to the outcomes of the global analysis performed to the collected data, the results of more specific analysis are also mentioned, according to the different levels of education.

Considering the complexity of the Educational System, there is an obvious need to review management and administration models, applying the principles of the Educational System Foundation Law published in 1986, in particular the principle of institutional autonomy [2, 3, 6-11].

Considering the relevant role of maintenance conceptual models in the development of maintenance auditing tools, this paper presents also an overview of maintenance conceptual models as well as a proposal for a maintenance conceptual model for Portuguese Educational Institutions and a school model that had supported the maintenance auditing tools' development.

II. REFERENCES TO PORTUGUESE EDUCATIONAL FACILITIES MAINTENANCE

Within organizations, maintenance strategies must result from the consensus and from a clear coordination between those responsible for managing the organization and those responsible for its assets' maintenance management and organization. Despite this, in teaching establishments the options concerning maintenance have been independent from the organization management within the educational system [3, 7-13].

The Portuguese Educational System Foundation Law, published in 1986, states that the dimensions of educational facilities must provide the possibility of receiving a reasonable number of students, in order to guaranty the necessary conditions for a good pedagogical practice and to promote a true school community. Simultaneously, the management of spaces, installations and equipment, human and material resources, as well as financial and administrative management, should contribute to the educational and academic success of each student [7].

The Portuguese Educational System Foundation Law also states that the construction and maintenance of buildings and equipment of the public school network, across the country, should be based on a policy that clearly defines the competencies for every stakeholder and that guarantees the availability of the necessary resources [7, 9, 12, 13].

In addition, the Portuguese Educational System Foundation Law stipulates that Governmental Bodies should develop "*a contingency plan for construction and rehabilitation of school buildings and their equipment, in the sense that the needs of the school system are met, giving priority to basic education*" [7, 9].

As regards the Educational System, the legislation published in Portugal is vast, but the reference to issues related to maintenance management and organization of school buildings is vague and sometimes even non-existent. The exceptions that could be found were exclusively oriented towards the assets assigned to preschool, elementary and secondary levels of education [3, 7-17].

Several studies concerning the Educational System have been carried out in Portugal. However, by the end of the twentieth century, the developed and published studies were

almost exclusively dedicated to Primary, Preparatory and Secondary schools, and until 2006 they were focused on areas such as pedagogy, politics and administration [3, 14]. In fact, the importance of the buildings' structure and equipment maintenance management and organization was far from being effectively recognized as a key element in the mission statements of the Portuguese school boards.

Until the beginning of the twenty first century, among the publications of the Portuguese Board of Education, a few consider the operational area of educational organizations and hardly any were found focusing on the importance of maintenance in educational facilities. As an exception the "Schools Operation, Maintenance and Safety Handbook" (MUMSE) may be emphasized, it is a 2003 reissue of the "Schools Maintenance and Utilization Handbook" earlier published in 2000 [12, 13].

Those publications were presented as informative documents, suggesting that "(...) *each school board should develop its own operation, maintenance and security manual (...)*" considering each building constructive characteristics as well as the installed equipment. They intended to raise awareness among school boards, and users in general, to the importance of preventing accidents, planning for safety and security. They also called the attention to the preservation of health conditions of buildings and equipment, as well as to the protection and preservation of their technical installations, and furniture [12-14]. The MUMSE suggests that when commissioning and at the acceptance of assets, namely of buildings and equipment, the management bodies of educational or teaching establishments "(...) *should be handed over a set of elements that constitute an authentic operation, maintenance and safety handbook*" [12-15].

Since the early years of this century, the market of building maintenance and rehabilitation has been experiencing a significant evolution and the growing importance of that market led to a significant number of national publications, as well as to a vast legislation regulating such activity. For example, the new regulation on energy efficiency of indoor air-conditioning systems in buildings, transposed into the Portuguese Legislation in 2006, also requires regular monitoring of maintenance practices over HVAC systems, not only as a condition of energy efficiency, but also to ensure the indoor air quality in buildings [16].

Although some parallels may be established, the specificity of the Educational System does not always allow documentation to be suitable to the reality of educational facilities. The educational establishments' maintenance policy reflects the general scenario described for buildings' maintenance, it is also the result of the evolution of the Portuguese Educational system over the last four decades, since the objectives defined for the educational system development have direct implications in the school assets preservation [3, 7-15].

The involvement of the central political authorities allowed the change of the described scenario up until 2006. Over recent years, it has been possible to find more publications, whether directly or indirectly related to the maintenance of educational

facilities, even though almost all of them were still devoted to non- higher education establishments.

In 2006, the political power recognized *"the progressive deterioration that over the past decades has been observed in the state of preservation of secondary schools, despite of all the initiatives that casuistically have been implemented in terms of facilities maintenance"*. It was also acknowledged that those casuistic initiatives *"have always been implemented sporadically, consubstantiating forms of superficial approach and only to meet specific needs felt in each educational establishment"* [3, 11].

Established in 2007, the "Parque Escolar, E.P.E." provides technical documentation in the form of accounting reports, reports of service quality, sustainability reports and several manuals. These documents make reference to the maintenance of educational facilities and equipment and it is stated that the *"solutions presented during the design phase should always consider three factors: initial cost, maintenance cost and operational cost"* [17].

It is acknowledged that the *"balance of those three vectors preconizes the best solution for design and execution"*. The school buildings operating costs are referred to be dependent on the installed equipment, reason why it is stated that the installed equipment must be *"not only robust in its operation but also in its use resistance, to the environment and in some situations, vandalism, without unreasonable increasing of the installation costs"* [18].

The Portuguese Court of Auditors has been publishing multiple reports with observations and data about the planning, management, development and execution of the Parque Escolar, E.P.E. modernization plan for the public network of secondary schools and other educational establishments under the responsibility of the Ministry of Education. Despite the references to facilities, systems and equipment maintenance, referred to in legislation and other publications that have just been mentioned, the Court of Auditors' reports identify the need to devote more attention to issues directly related to the maintenance management and organization of school assets.

III. MAINTENANCE CONCEPTUAL MODELS

As new maintenance techniques have become available, and the economic implications of maintenance actions have been perceived, it would be expected a direct reflection on planning policies for maintenance activities and on maintenance strategies selection by organizations [19].

As a result of the developments in the area, maintenance management is no longer considered as a pure technical function, it has started to incorporate considerations of cost-benefit. Business context issues related to the institutions, and their functional requirements also play an important role. Maintenance management should therefore cover operational issues (such as the planning of maintenance work), tactics (such as decisions relating to the maintenance policy to be adopted in the long-term) and strategic procedures (such as the

acquisition of new facilities, design decisions and policies of human resource management) [19-21].

Such development in maintenance management incurs a sharp need for various techniques that would facilitate decision making in the context of assets maintenance management and organization, such as [19]:

- Statistical analysis tools for predicting equipment's failure behavior,
- Mathematical models to optimize the maintenance policy parameters (e.g. predetermined preventive maintenance frequency), decision criteria concerning e-maintenance decision aids for outsourcing decisions, etc.,
- Conceptual models and decision schemes for determining the more suitable maintenance concept.

In the sixties of the twentieth century, most of the publications in the area of maintenance were mathematically oriented and mostly focused on reliability. In the following decade and early eighties publications were more focused on maintenance policies optimization, including the optimization of preventive maintenance intervals, planning of group replacements and inspection modelling. Despite this evolution, the models presented at this stage were still often more focused on mathematical tools than on realistic assumptions and hypotheses. This caused an unfortunate gap between academics and practitioners in the area of maintenance, with practitioners considering the published models to be excessively theoretical [19, 20, 22-24].

More recently, in addition to traditional maintenance models, there is an increasing number of publications devoted to the study of specific objects and the growing exploration of a more diverse range of models and concepts, such as maintenance strategy design models, concepts of remote maintenance, service parts supply policies and maintenance conceptual models. Simultaneously, there has been a greater acceptance of the scientific work performed by the practitioners in the field of maintenance [19, 20, 22-27].

A. Overview of maintenance conceptual models

Apart from the generic reference to conceptual models of asset management, publications can be found addressing the particular case of maintenance management models and others on the development and application of conceptual models, both in the business sector and in public institutions [23, 27-44].

Among the various proposals found, the conceptual models released by the Global Forum on Maintenance and Asset Management (GFMAM) and the European Federation of National Maintenance Societies (EFNMS) may be mentioned. Fig. 1 shows the conceptual model for assets management proposed by the EFNMS.

Maintenance conceptual models are based on the assets' life cycle, regardless of whether they are structures or fixed

equipment, over several stages, from conception to the disposal of the asset, as shown in Table 1 [3, 21, 43, 45-47].

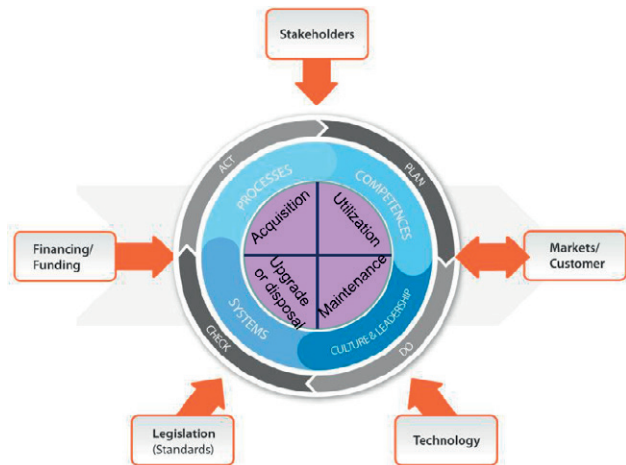


Fig. 1. EFNMS Conceptual model of asset management [42, 43].

TABLE I. STAGES IN THE LIFE CYCLE OF AN ASSET [3, 21, 43, 45-47].

Life cycle Stages	
Preparatory	Conception and Designing Manufacturing and Assembly Procurement and Installation Accepting and Commissioning
Operational	Service Maintenance Promotion Planning Disposal

Generically, the investment associated with the acquisition of an asset is expected to be compensated for by the return generated by it. In the particular case of public institutions, such as public schools, the focus is not on the maximum possible profit, but in the optimization of the costs associated with the assets, although their performance should also be considered here as a way to ensure that the asset is able to meet the required functions [46]. On these assumptions, Mollentze presented a holistic model that is summarized in Fig. 2.

When modeling maintenance activities it should be considered its relationship with other areas that the organization considers relevant. This allows efficient solutions, with the possibility of cost control. In this scenario, it becomes important to define structured communication channels that allow sharing relevant information [36]. Based on a holistic view of maintenance, the model of Fig. 3 presents a proposal for a conceptual model regarding the information relevant for maintenance, also considering other activities and typical areas of business entities.

Several models have been developed with the aim of improving and optimizing the maintenance service. As a result of this, it has become clear that the definition of policies and strategies and the understanding of the efficiency and

effectiveness of the maintenance department continues to present opportunities for improvement [19]. An effective and efficient Maintenance Management Model must place users and their needs at the center of the organization, abandoning the traditional options for using corrective or preventive strategies merely based on the assets condition analysis and on the available resources [3, 23, 39].

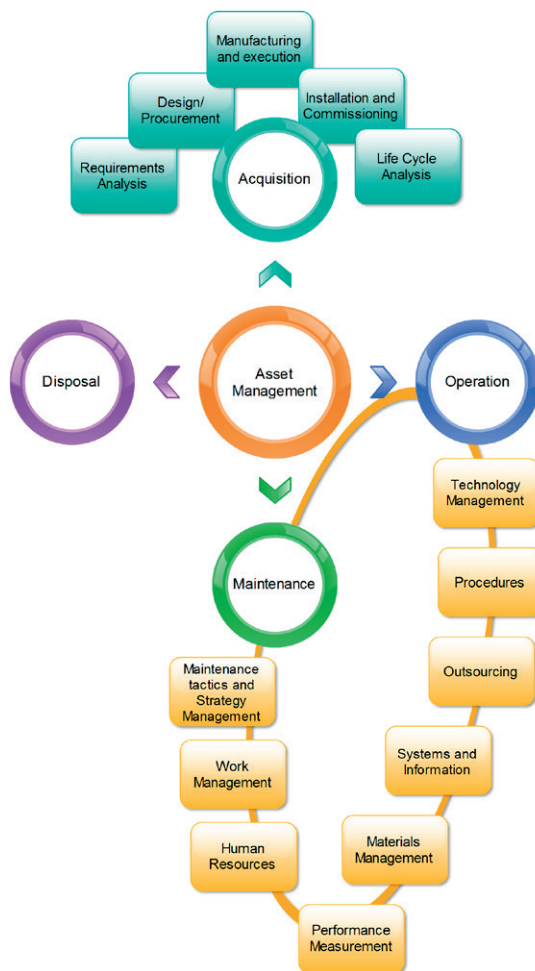


Fig. 2. High-level model for asset management and models/framework for Acquisition and Assets Operation and Maintenance [46]

B. Proposal for a maintenance conceptual model for Portuguese Educational Institutions

As mentioned before, the approach to maintenance management and organization in Portuguese Educational Institutions has been heavily dependent on financial constraints and on the buildings' state of disrepair. Maintenance management and organization decisions heavily dependent on these two factors tend to be not only damaging to the structures of the buildings, technical installations, engineering services and fixed equipment, but also to the establishment itself and to the assets. These scenarios are more expensive, and also lead to user dissatisfaction [39].

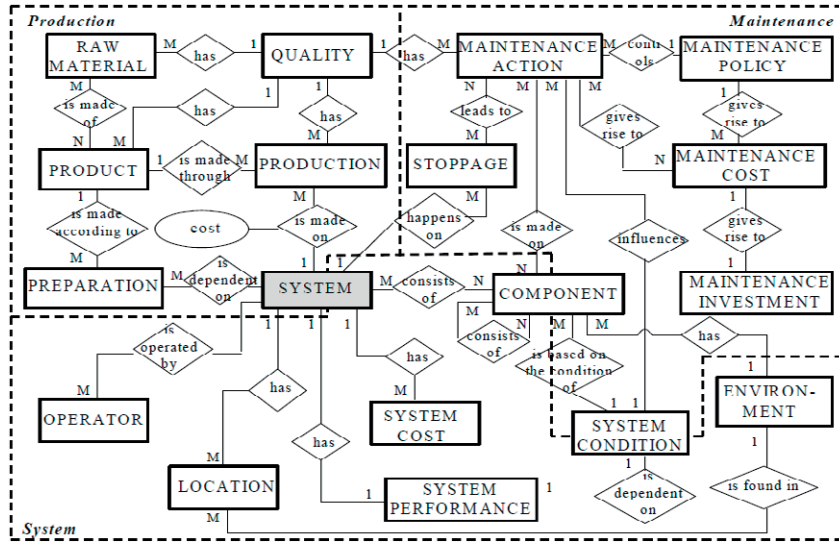


Fig. 3. Conceptual information model showing a holistic representation of maintenance [36].

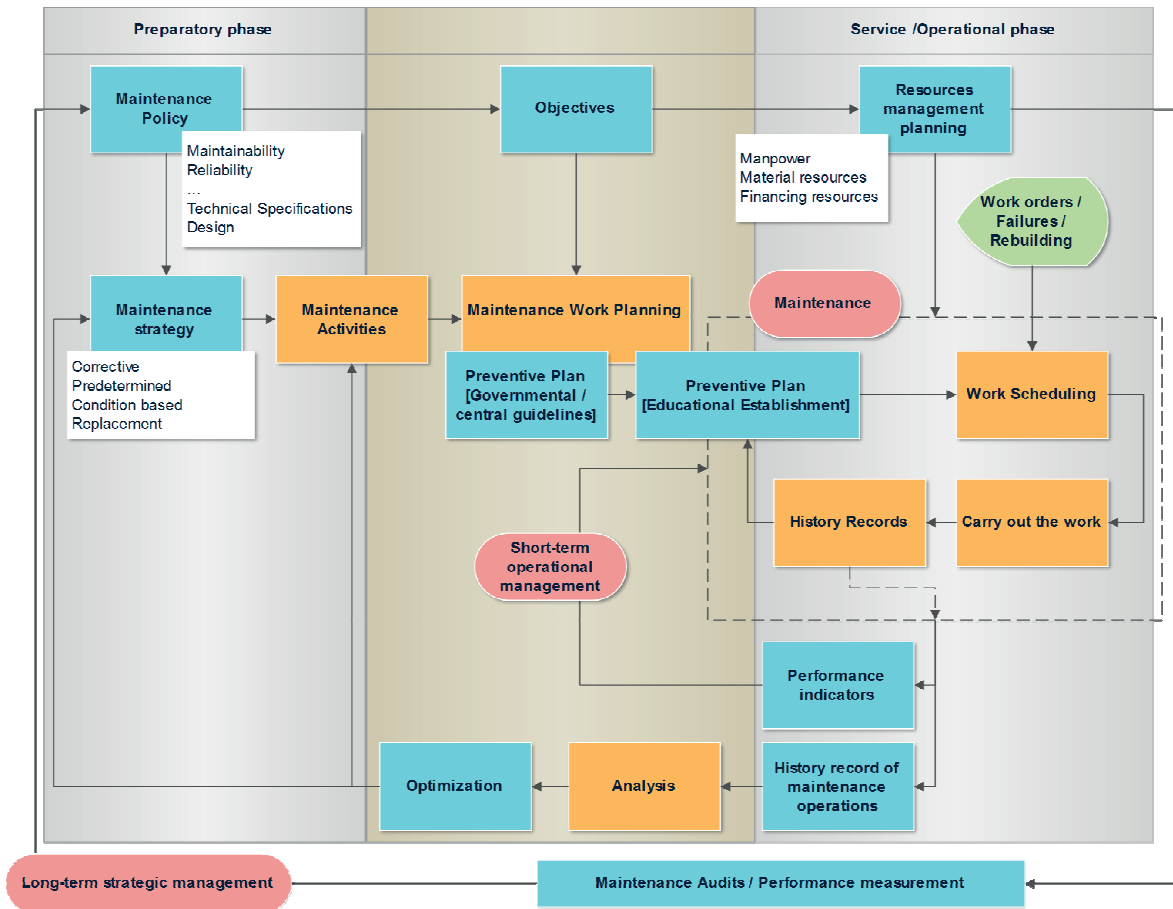


Fig. 4. Conceptual Maintenance Model suggested [3].

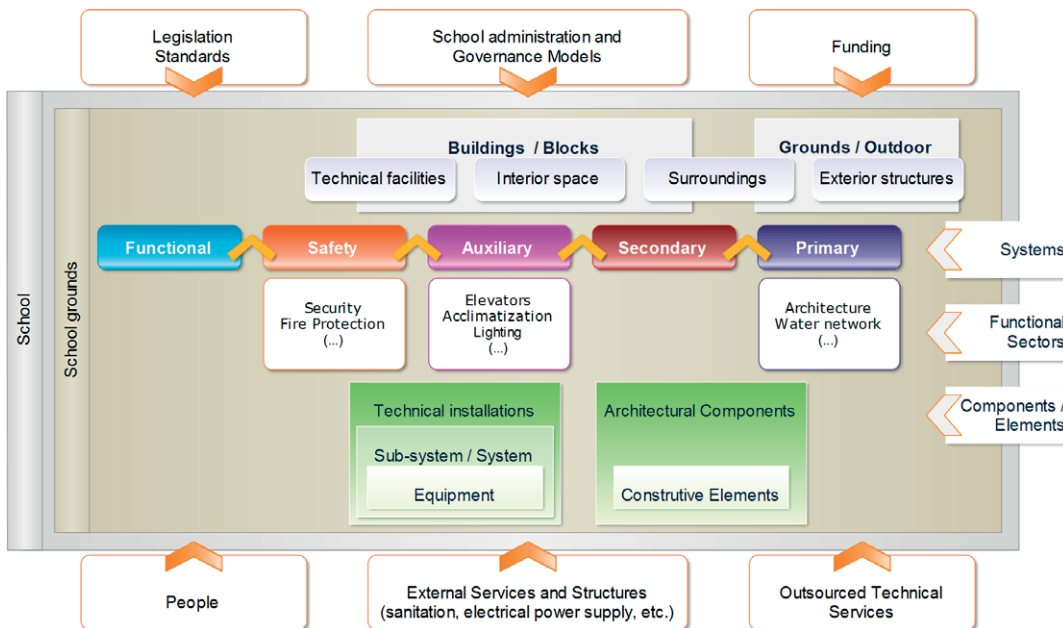


Fig. 5. School Model supporting the development of maintenance auditing tools for data collection [3].

Even though the Portuguese Educational System Foundation Law states that the school buildings need to ensure "conditions of a good pedagogical practice and the promotion of a true school community", the existence of an integrative maintenance management model for Portuguese school building assets is, however, unknown.

Based on the literature review, the framework and structure of the Educational System and on the successive Portuguese governance models, considering the related legislation and also publications in the area of maintenance management and organization, the conceptual maintenance model in Fig. 4 was developed. This conceptual model guided the methodology followed in the study mentioned here and also served as the basis for the development of suitable maintenance audit tools.

The conceptual model proposed in Fig. 4 reflects the concept that the compliance with operational requirements of the maintenance system (such as the maintenance planning) are dependent on tactical and strategic issues. Indeed, the preparatory phase involves the development of strategies for the acquisition of new facilities and fixed equipment in addition to the consideration of tactical issues, such as the definition of maintenance strategies, which naturally affect the identification of the maintenance work. It is important to note that each school is unique, so it is particularly important to adapt any central guidelines to each situation. Inevitably, the planning and scheduling of maintenance are also dependent on strategic decisions related to resources management policies, during the operational phase.

Work planning and scheduling are essential in any attempt to improve the process, since they allow the reduction of corrective work creating the possibility of implementing new practices which should be preventive in nature. Efficient

structures allow the achievement of ratios of 80% for preventive maintenance work to 20% or less corrective maintenance, which allows one to explore new approaches and to implement more efficient practices [48].

The information concerning the operational phase will be essential for retrofitting decisions related to procedures or systems, both with regard to the short-term operational management and to the long-term strategy and underlying tactics.

IV. DEVELOPMENT OF MAINTENANCE AUDITING TOOLS

Maintenance conceptual models explore the concept that improvements in maintenance management efficiency depend on a first evaluation phase, based on maintenance audits [46].

The specificity of the Portuguese several levels of education refers not only to pedagogical practices but also to spaces, installations and equipment policies management, human and material resources management, as well as financial and administrative management. It was decided to evaluate the situation for each level of education separately, not only in terms of maintenance management, but also regarding building characteristics, building systems, safety improvements and technology [3].

Since no survey of the Portuguese Educational System, referring to those areas in particular was available, several questionnaires have been developed, to be answered by each school board or institution responsible, with the aim of collecting information for later analysis. The developed questionnaires, were modelled according to the abovementioned specificity [3-5, 14, 15]

It should be mentioned that the conceptual model followed in the development of auditing tools for data collection is based on the need to collect information about all the schools' assets according to the school model used to support the development of auditing tools for data collection displayed in Fig. 5. Simultaneously, it is focused on the framework of Maintenance and its relationship with resource planning associated with the operational phase, as indicated in Fig. 4.

V. SOME RESULTS AND CONCLUSIONS

As several models have been developed with the aim of improving and optimizing the maintenance service, it has become clear that the definition of policies and strategies and the understanding of the efficiency and effectiveness of the maintenance department continue to present opportunities for improvement. The process of improving maintenance in organizations heavily dependent on preventive maintenance strategies leads to improvements that are rarely immediate. In most cases, the transition does not present significant technical difficulties, but nonetheless the improvement due to choosing preventive maintenance strategies managed proactively can take from three to five years [48]. Indeed, it becomes necessary to change the organization's culture, namely the way according to which the same organization faces the maintenance function, which must be assumed as a central process [48].

An effective and efficient Maintenance management model must place users and their needs at the center of the organization, abandoning the traditional options for using corrective or preventive strategies merely based on the assets condition analysis and on the available resources.

In order to manage the available resources in an effective way, it is extremely important that educational organizations may have updated, detailed and accurate information about the buildings, their systems and equipment, and the way they are managed. In this scenario, maintenance audits provide a framework for organizations to systematically review, analyse and recommend improvements in maintenance management performance.

The results of the case study regarding the Portuguese secondary school buildings emphasise the need to develop periodic asset inspections, not only to verify their condition, but also as a support to establish retrofitting maintenance programs.

Not only school board administrations but also the authorities responsible for educational system management must be aware of the importance of school buildings' assets maintenance management and so training must be considered. On the one hand areas such as maintenance management and organization provide the indispensable technical support for planning and scheduling maintenance activities of the educational institutions. On the other hand the former provide the backing for inspection activities, reporting and analysis of the collected data. Additionally, team management, leadership and motivation are a valuable support for school managers to deal better with maintenance personnel.

Unquestionably, school buildings have special management needs but they also present unique development challenges in terms of new studies and applications. Simultaneously, school organizations may have a privileged influence both in individuals and in institutions.

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