Life cycle cost as a tool in physical asset management – Application at the Military Academy Headquarters Barracks

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Extended Abstract

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Abstract

The objective of this research was to develop a methodology supporting LCC analysis and present its practical application in a building at the Military Academy Headquarters, thereby, providing a management tool for physical assets.

The analysis demonstrated the main expenditures in the building, as well as their distribution. A degradation model was also elaborated to estimate an intervention schedule for the exterior façade maintenance.

Two measures were suggested which would reduce the life cycle cost of the building involved in the study: installation of water flow restrictors in taps and showerheads and substitution of existing light bulbs with LED light bulbs.

1 Introduction

Buildings are constructed to provide their owners and residents with the means to achieve a variety of finalities and carry out diverse functions. From among this variety of functions emerge different types of buildings, such as residences, hospitals and schools, military, business and industrial, among others.

Normally, the construction of a building represents a substantial investment with a service life that may span various generations. These investments are carried out with the intention of creating benefits provided by the new functionalities, increased productivity or improved living conditions. This leads to increased prosperity for communities in general.

Due to the diverse components and elements which comprise a building, with varying durability characteristics among them, the premature failure of any one could potentially compromise the performance of the system as a whole. Furthermore, the change of paradigms, with increasing emphasis on the management of existing assets, as opposed to new construction, has occurred, in light of the current concern with building life cycles and engineering infrastructures.

Given the diversity of existing building types, namely public buildings, (e.g. government buildings, health facilities, schools, correctional facilities) which act as the basis for the life style of any society guided by modern Western standards, the decisions regarding these may have significant consequences for communities. Therefore, the management of these physical assets is relevant, so that cost control can become increasingly more efficient, seeking to maximise the value generated by the asset as a whole.

Relative to the Armed Forces, and specifically the Military Academy, there is growing concern regarding its building complex. Solutions are necessary to improve the life cycle of the assets as a whole, as is an assessment of the influence presented by the constraints and uncertainties, existing in any scenario.

2 Life Cycle Cost and Physical Asset Management

Even with the availability of funds, building management is a complex problem and the effects of insufficient allocation of funds are well documented, especially in public buildings. In the USA, the American Society of Civil Engineers reports that the global condition of public infrastructures is only D^+, equivalent to a classification of “Poor” (American Society of Civil Engineers, 2013).

With respect to Europe, the construction sector generates approximately 10% of the GDP and creates approximately 20 million jobs, essentially in small and medium sized businesses (SME’s). However, these figures have decreased approximately 16%, which led the European Commission to establish short term objectives to aid in employment growth in this sector (European Commission, 2012). The negative evolution of this sector in Europe was also felt in Portugal. Family income, the job market and interest rates were decisive in this evolution (Nunes, 2011).

In view of infrastructure ageing in many developed countries, Portugal included, together with a stabilisation of the necessity for new infrastructures and the constraints in terms of resource consumption (e.g., materials, funds, energy), there has been a transition from a significant amount of investment in new construction to the renovation of existing constructions instead (Cohen, 2004; Laefer & Manke, 2008).

The application of methodologies intended for the management of physical assets, which has been verified in sectors such as water supply, contrasts with the slow pace registered in the context of buildings. This is due to the challenge of implementing an approach that is consistent with all of the areas involved in buildings (Grussing, 2015).

The analysis of life cycle cost can be used as a tool, aiding in decision-making and optimisation of the commitment between time, cost and performance (Özkil, 2003). Six fundamental steps can be defined to analyse life cycle cost (National Research Council, 1991): i) defining of the objectives; ii) identification of alternatives; iii) defining of possibilities; iv) benefits of the project and costs; v) assessment of alternatives; and vi) deciding from among the alternatives.

In light of the scenario of recovery in Portugal, the Military Academy was not indifferent to the changes, and in its 2012-2016 strategic plan, specifically pertaining to support, it referred to the following fundamental areas of interest to security: materials, infrastructures and the financial aspect, always with a concern for the maintenance, conservation and optimisation of materials and infrastructures, as well as promoting financial sustainability (Academia Militar, 2012).

Relative to the increasing interest in physical asset management, standards were created to be applied in any organisation where physical assets are key or critical factors in achieving the organisation’s objectives. Therefore, in 2004, *Publicly Available Specification* (PAS 55) was established, which was later revised in 2008. In 2014, a group of ISO 5500 standards were established, with three interconnected publications.

Asset management (AM) entails establishing a balance between costs, opportunities and risks and the asset's performance, so that organisational objectives can be achieved (ISO 55000, 2014). Included in the requirements established in ISO 55001 is the necessity of taking the asset's life cycle into consideration. Along those lines, the ISO 15686-5:2008 standard is the main reference for LCC analysis in buildings and infrastructures.

After analysis of available standards and documents which address AM, specifically the analysis of each LCC, it becomes clear that four distinct phases are relevant to every one: i) construction phase; ii) operation phase; iii) maintenance phase; iv) demolition phase.

3 Methodology

Different standards and documents were consulted to develop a LCC analysis methodology to be applied in a building.

As previously mentioned, the ISO 15686-5:2008 standard is the foundation for the development of the models presented as possibilities for analysis and it guided the development of the methodology.

Based on the aforementioned standard, the consultancy group, Davis Langdon (Langdon, 2007), developed a methodology which establishes 15 steps which should be followed to analyse the LCC of an asset.

The principal stages of the LCCA defined in Figure 1 were specified in fifteen fundamental steps, based on the aforementioned methodology. Alterations to that core methodology were proposed, taking into consideration other references used and an attempt to facilitate its implementation, namely through the change in sequence of some of the steps (Table 1).

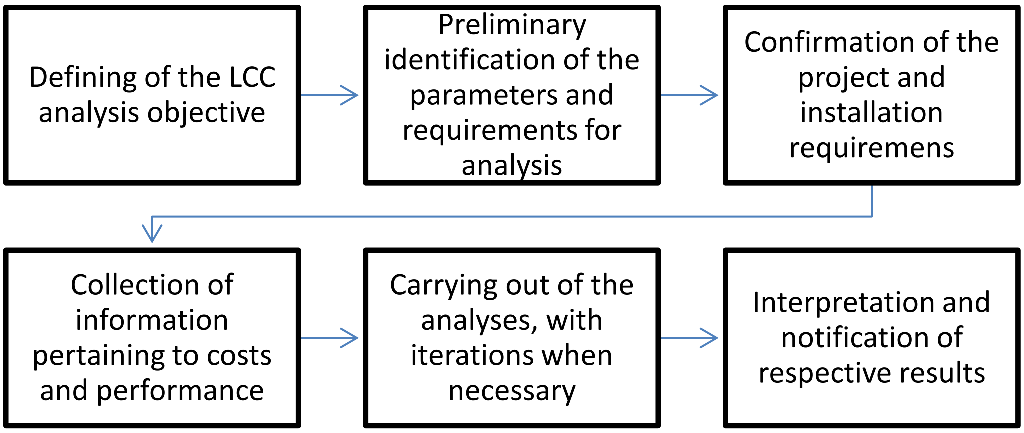

Figure 1 Main process of LCC

Table 1 General overview of the steps in the adopted methodology

Step	Result
1 – Identification of the main objective of the LCC analysis	• Motive for the carrying out of LCC analysis
2 – Identification of the requirements of the project and the asset	• Gathering of information necessary for analysis
3 – Identification of the analysis's context	• Context of the LCC's analysis application • Defining of the asset's phase • Limits of the analysis
4 – Identification of sustainability's contribution	• Associated environmental impact • Include the LCA in the analysis
5 – Identification of the analysis period and the methods of economic assessment	• Period of analysis to be considered • Methods of economic assessment
6 – Identification of the necessity for additional analyses	• Associated risk • Awareness analyses
7 – Defining of the assessment criteria and cost categories	• Cost categories (constitution of a CBS)
8 – Selection of alternative options to be analysed	• Assessment of alternatives relative to the client's objective
9 – Collection of information from temporal cost profiles	• Collection of financial and economic information
10 – Preliminary risk assessment (optional)	• Assessment of the assumed risk/uncertainty
11 – Revision and confirmation of analysis parameterisation (period, financial parameters and additional analysis)	• Corroboration of the analysed parameters (period of analysis, financial parameters)
12 – Execution of a financial assessment	• Execution of the financial and economic assessment
13 – Execution of an awareness analysis and detailed risk assessment (optional)	• Execution of awareness analyses • Execution of risk analyses
14 – Interpretation and presentation of initial results	• Revision and interpretation of results • Presentation of initial results to client (through graphics, charts...)
15 - Presentation of final results	• Final report

4 Case study

4.1 Framework

The MA is a Public Institution for Higher Military University Education whose mission is to train officials for the permanent Armed Forces and *Guarda Nacional Republicana* (Republican National Guard) (*Law-Decree No 27/2010 of 31st March of the Ministry of National Defence*, 2014).

The MA is comprised of two separate campuses, with Headquarters in Lisbon and barracks in Amadora. The practical application of the adopted methodology was applied to the building complex at Headquarters, more specifically the barracks for students.

Figure 2 Barracks building in analysis

The building in question is divided into three main parts. One is housing for the cadets attending the fourth year of MA, forming the fourth company of students. Another is for the official students of Engineering, Transmissions, Material Service and Medicine, as well as student cadets of Medicine, forming a fifth company of students. The third building is for female housing, rooms for officials and offices. Adjacent to this building are shower facilities used by students, as well as visitors to the MA complex, who practice sports activities there.

The finality of the LCC analysis does not include construction costs, being that information does not exist relative to those costs. An estimated construction date, relative to the building's age creates many difficulties, which lead to an elevated level of uncertainty in is determination.

4.2 Background Data

To proceed with LCC analysis, information was collected to facilitate that task. At the financial department of the MA, data was collected, relative to the energy expenses and water and gas consumptions. To obtain information on the interventions carried out in the building, data available at the *Direção de Infraestruturas do Exército* (DIE – Directorate for Military Infrastructures) was consulted. Taking into consideration the experience of living at the MA, as well as the direct contact between the students who attend the Academy, it was possible to collect data which explained the different building consumptions.

From among the existing cost categories, the ones which were chosen to be part of the analysis, with respect to the obtainable information, are represented in Figure 3.

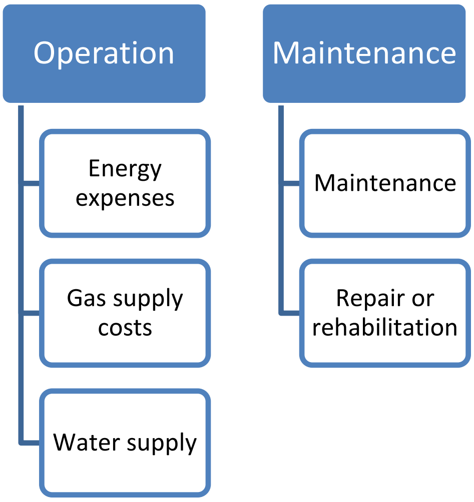

Figure 3 Cost categories for analysis

The study of these categories to analyse their economic impact throughout the years involved different inflation rates, whose values were obtained from PORDATA platform. In this manner, distinct values for the economy's global inflation rate, the inflation rate of water, electricity and gas and the inflation rate of building maintenance were obtained.

Another assessment criterion used in the LCC analysis was the refresher rate, calculated using the following formula:

$$Ta = [(1 + T1)(1 + T2)(1 + T3)] - 1$$

where:

T1 actual yield

T2 risk premium

T3 inflation

The constraint present in this phase was the fact that data was only available for the period between 2010 and 2014. The remaining figures are estimates for the chosen analysis period of 50 years.

Water consumption in the building is approximately 60% of the total registered for the barracks. Therefore, measures to reduce this figure are the most appealing. In addition to the direct cost of water, its use has associated added energetic expenses related to the heating of bathroom water.

After a detailed analysis of water consumption, the following distribution, presented in Figure 4, was obtained.

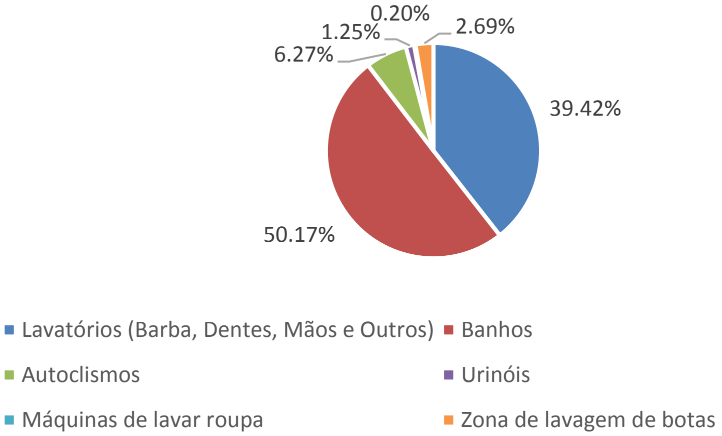

Figure 4 Distribution of water use in the building

With respect to electric consumption, the room which presented the highest values of energy consumption was studied. Being that the main equipment using energy is found in the bedrooms and it is here where students spend most of their time, it was determined that the highest values for energy consumption could be found there. The lack of centralised heating in the bedrooms means that during the winter, the thermo ventilator is used intensively. This equipment consumes, on average, 2000W.

The distribution of consumptions by equipment in the rooms is illustrated in Figure 5.

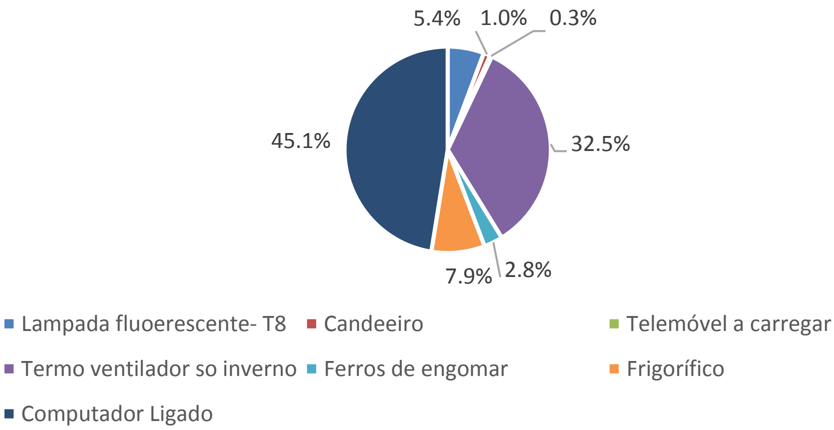

Figure 5 Distribution of electric consumption in rooms

Gas consumption in the building pertains only to water heating and represents approximately 51% of the total registered in the barracks.

A degradation model was also developed to study the maintenance schedule of the exterior façade which is painted. Placing the facade within the different levels of degradation adopted by Magos (2015) and relating the adopted level with the severity of standard degradation (S_w) presented by Chai (2011), it is concluded that the value of S_w for the building is between the interval [10%;20%], with 15% being adopted. Using equation 1, an interval for intervention of 14 years is calculated.

$$Sw = -4.207 \times U + 1.757 \times DM + 4.655 \times H - 2.692 \times A + 1.136 \times I + 0.006 \times I^3 \quad (1)$$

4.3 Results of the LCCA

The process adopted to calculate the LCC of the building is represented in Figure 6. The implemented process originated from the fact that the only known energy consumptions of the building were those which were registered between 2010 and 2014, making it necessary to estimate the consumptions in the years prior to 2010 and those after 2014.

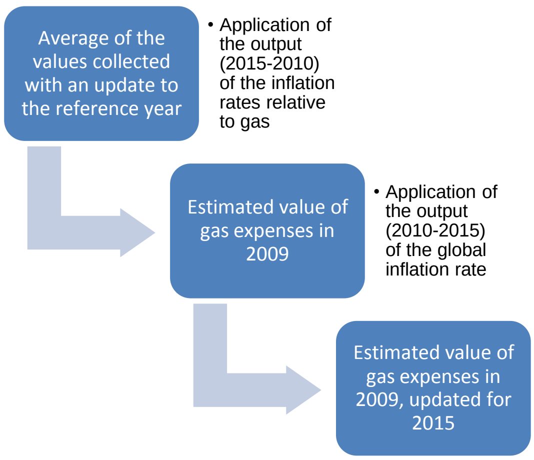

Figure 6 Process used to update the existing costs in the LCC analysis

After the application of the previously shown process, a LCC of €13,097,128.68 was calculated for the building.

Taking into account the analysis period, distinct awareness analyses were carried out which verified that the occurrence of maintenance procedures in the building leads to the maintenance variable becoming the third most significant, ahead of energy expenses. Transversely in the analyses, water consumption is always the parameter with the greatest awareness in the analysis. The following figure demonstrates the examples:

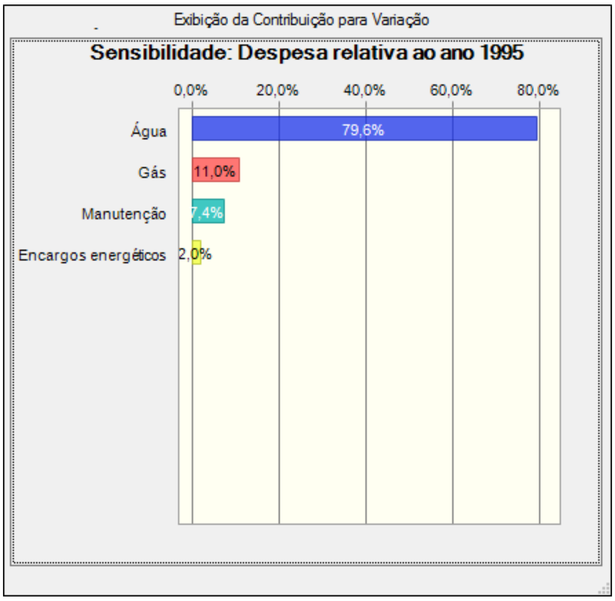

Figure 7 Awareness analyses carried out

The risk analysis assumes a level of certainty of 80%, relative to the data obtained. It can be stated that within the percentage of certainty established, costs will not exceed €232,089.64 (Figure 8).

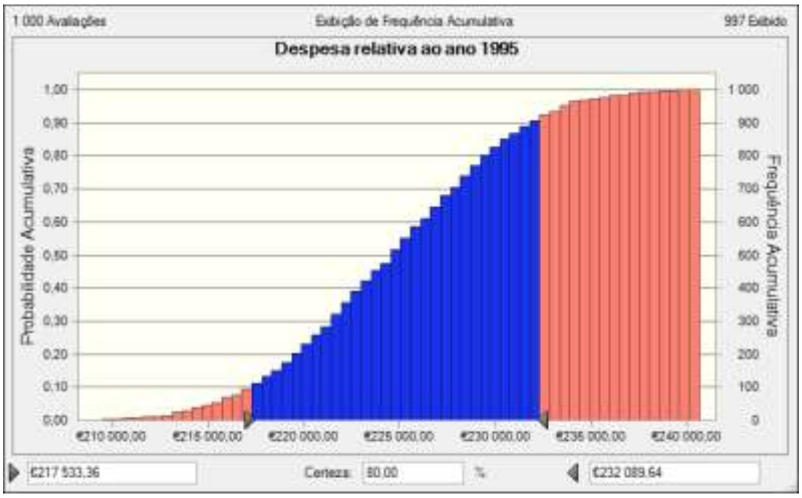

Figure 8 Risk Assessment – Graphs of accumulated frequency

The introductions of measures which result in the reduction of water consumption are those which will represent the greatest variability in results, taking previous analyses into consideration. However, measures which influence the reduction of energy consumption should not be excluded.

Therefore, the following were considered: i) substitution of tubular T8 fluorescent light bulbs of 36W, for tubular LED light bulbs of 20W; and ii) installation of water flow restrictors in the shower heads and taps of the facilities

As can be verified in Figure 10, and relative to the baseline scenario, the savings resulting from the measures related to water consumption reach approximately 50%.

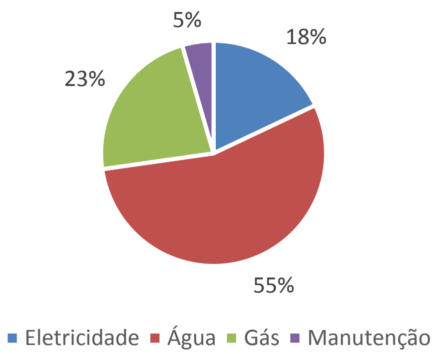

Figure 9 Distribution of building expenses in the baseline scenario

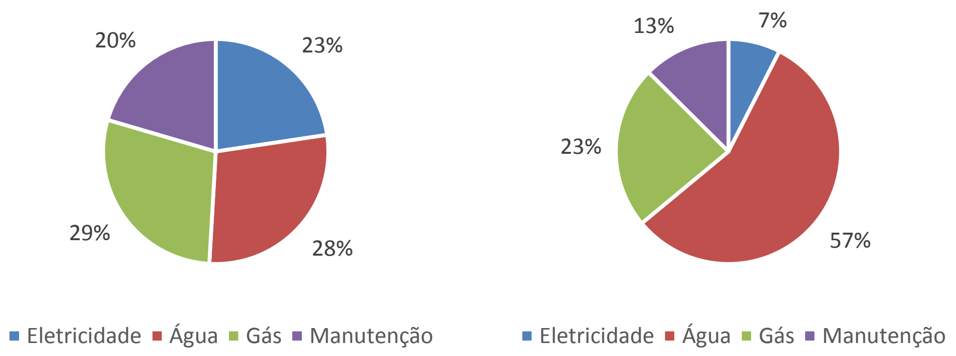

Figure 10 Distribution of the expenses after the implementation of the proposed measures (Water flow restrictors and LED light bulbs, respectively)

5 Conclusion

The present dissertation intended to develop a practical methodology to analyse the LCC of buildings. The scant bibliography related to this topic in Portugal led to the consultation of international publications, specifically standards..

The difficulty in gaining access to the data, as well as a lack of data bases which register maintenances using internal means were two challenges which hindered a more rigorous analysis of the building.

The development of the degradation model, relative to the façade maintenance took various factors into consideration: urban density, proximity to the ocean, humidity levels, the type of finish, as well as age.

The consumptions verified in the building being analysed represent a significant segment of the expenses in the barracks. For this reason, it is of great interest to adopt measures which reduce costs significantly. Therefore, an investment in these measures is a solution which will produce benefits for the institution in the long term.

The installation of water flow restrictors in taps and shower heads in the facilities, as well as the substitution of the current light bulbs for LED light bulbs are measures which result in a strong economic impact, as well as environmental, at the MA. The first option is the one which is economically more advantageous. Therefore, considering the baseline scenario presented, the alternatives will lead to a reduction in the LCC of the building, presenting savings of approximately €3M if there is a joint implementation of the alternatives.

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