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Life cycle cost as a tool for asset management – Application to the quartering of Military Academy in Amadora

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Extended abstract

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October of 2016

Abstract

The main goal of this work is to develop a methodology to calculate the life cycle cost (LCC) of an asset and its subsequent application to one of the buildings inside the Military Academy in Amadora. The military buildings have very specific features, and specially, a bigger longevity when compared to the other assets. The methodology used in this document covers the specifics of this type of buildings, and it's based on other methodologies that are seen as international references.

After the application of this methodology to the case of study, it is concluded that the impact of the maintenance and operation costs are greater than the impact of the initial construction costs. The construction costs are only 41% of the LCC, less than half. These data demonstrate the importance of considering the costs of the entire life cycle, rather than considering only the acquisition price.

It is also concluded, that the installation of more efficient lamps, dual flush flow meters and flow reducers, would accumulate savings of about 15% in the LCC of the building.

1 Introduction

The Portuguese army is an institution with a unique history and a very specific mission, the military defense of the republic. Because of this very particular mission, the institution has become the owner of a vast tangible and intangible heritage over the years. The tangible heritage, mainly buildings, were constructed to house personnel and to provide conditions for the preparation of forces to the most diverse types of tasks. The referred buildings are strategically located throughout the Portuguese territory, and require permanent management of different levels.

In this context it makes all the sense to pay serious attention to the management of physical assets. This way the army can take advantage of his buildings at maximum level and during the maximum period possible.

In the current conjuncture, a more efficient management of existing physical assets could bring several advantages directly to the army, indirectly to the country, and even possibly to the environment. Given the need to make the most of the existing buildings, the objectives of this dissertation emerge:

1. Propose a methodology for the organization and calculation of the LCC.
2. Application of the methodology to the quartering of the Military Academy in Amadora.
3. Develop a degradation model related to one building element, in order to predict future costs.

2 State of the art

2.1 General considerations

In an economic environment that requires more restrictions every day, and taking into account the aging of the infrastructures in many developed countries, like Portugal, we are witnessing a transition from a significant portion of investment in new construction to the rehabilitation of existing structures (Laefer & Manke, 2008).

This transition is occurring, mainly, due to economic factors. These factors lead to a growing concern about the need to determine the durability of the materials, components, structures and buildings. The cost of the buildings, the annual costs of maintenance and operation and the promotion of competitiveness in the industry, are some of the reasons that justify the need to take the maximum advantage of the existing resources. Other factors that are also contributing to the growing concern referred, are related to the environment. Shortages of materials and energy resources, greenhouse gas emissions, and the impact caused by construction in general, are some of the reasons to focus the investment on the management and rehabilitation of the existing buildings (Hovde & Moser, 2004).

The military forces in general, and the army in particular, are institutions with high susceptibility to changes. These kind of institutions are constantly adapting accordingly to the needs of the nation, to their own needs, and to the eventual paradigm changes that may occur. On the other hand, military buildings in general are buildings where the utilization phase can easily achieve hundreds of years.

2.2 Asset management

The origins of asset management are hard to determine. However, the property management ideologies are not exactly recent. Organizations have been managing their assets for thousands of years, but not with as many conceptual dimensions as they actually do.

The actual international reference standard about asset management is ISO 55000 (2014), which included the participation of thirty countries and took about four years to be developed.

This standard refers to an asset as an article, object or entity that as actual or potential value to an organization. In the same standard, it is also defined the concept of asset management as the coordinated activity of an organization to create value from their assets.

The designation of physical asset comes as a complement to the asset designation, when it refers to items such as buildings, electric cables, water pipes, rails, and other materials and components. It excludes financial and human assets. Physical assets have characteristics such as the loss of value over the course of time, deterioration of its condition over time and use, among others.

Given these characteristics, the correct management of this assets can bring remarkable benefits. Examples of the mentioned benefits are:

- Total cost reduction associated to the asset operation.
- Maximize the performance of the asset.
- Reduction of potential health impacts caused by the deterioration of the asset.
- Reduction of security risks related to the use of the asset.
- Minimize the environmental impact.

A good asset management will provide the best benefits to the organization that owns the asset (Davis, sem data).

2.3 Life cycle cost

Generally, when someone or some entity intends to acquire an asset, they want to pay the lowest possible price for it. However, the cost evaluation of the entire life cycle of an asset usually results in attractive savings.

The reference standard about the subject is ISO 15686-5 (2008), which defines de LCC of an asset as the cost resulting from its entire life cycle, or the cost of all its parts while fulfilling the performance requirements (ISO 15686-5, 2008). Other definition of LCC was suggested by Langdon (2007). This definition states that the LCC of an asset is the cost that includes all the costs related to the asset, since the design and construction, till the end of life, including the costs related to the operation phase, costs related to maintenance and costs related to eventual rehabilitation works (Langdon, 2007).

2.4 Degradation models

The materials by which the buildings are composed are diverse. Each of these materials has different characteristics and properties. This means that its behavior will also be quite different. To further accentuate these differences, the conditions of application and use, as well as the environment that the materials are exposed to, can also be different. For instance, a material that is exposed to an external environment, will not behave the same way as if it was in an internal environment.

The reasons exposed lead to the development of degradation models. This models can be either deterministic, probabilistic or engineering models (Paulo, Branco, & Brito, 2014).

3 Methodology

The calculation of the LCC is an iterative process. In each phase of the project, from conception to end of life, the previous assumptions must be confirmed, and the calculation of the LCC must be refined step by step in order to provide results with the highest degree of certainty possible (TG4, 2003).

In the present document it will be adopted a methodology resulting from the congregation of two main international references, the approach proposed by ISO 15685-5 (2008) and the approach proposed by the consultant Davis Langdon in 2007. These two approaches are compatible, measuring by the fact that the second one was developed in order to detail the application of the first one, attending to a request of the European Economic Community. In addition to these two main references, the proposed methodology (Table 3.1) also contains the contributed of other international publications.

Table 3.1-Summary table of the methodology to adopt.

Step	Procedures
1-Identify the main purpose of the LCC analysis.	• Identify clearly the purpose of the LCC analysis. • Identify possible and achievable results.
2-Identify asset requirements.	• Identify key aspects of the asset (functions and characteristics). • Gather information about the performance level and quality of the asset. • Specify possible restrictions.
3-Identify the scope of the LCC analysis.	• Identify the scope of the analysis. • Identify the scale of application.
4-Identifify the contribute of sustainability to the analysis.	• Identify environmental costs to be included in the LCC analysis.
5-Identify the period of analysis and the methods of economic evaluation.	• Identify the period of analysis to adopt. • Identify the method of economic evaluation to be used in the analysis.
6-Identify the need for additional analysis.	• Preliminary assessment of risks/uncertainties. • Identify the need of a formal risk management plan. • Decision about the risk procedures to adopt.
7- Definition of evaluation parameters and cost categories.	• Identify the parameters used in the analysis. • Define cost categories in order to organize costs.
8-Identify the options to be analyzed in the LCC analysis.	• Identify a role of options to be analyzed and studied.

9-Assemble cost and time data to be used in the LCC analysis.	• Identify the relevant costs for the analysis. • Identify values for each costs. • Identify time related data.
10-Preliminary risk analysis (optional).	• Qualitative risk analysis - Update risk data. • Confirm the scope and extension of quantitative risk assessment.
11-Revision and confirmation of financial parameters and period of analysis.	• Revise the parameters value and adjust them if necessary. • Confirm the period of analysis based on the new data.
12- Economic evaluation.	• Construction of the worksheet. • Data insertion and calculation.
13.1-Sensitivity analyses (optional).	• Carry out a sensitivity analyze it necessary. • Results interpretation.
13.2-Detailed risk analyses (optional).	• Quantitative risk evaluation. • Results interpretation.
14- Initial interpretation and presentation of the results.	• Initial interpretation of the results of the LCC analysis • Results Presentation to the interested parts.
15- Final results presentation and final report.	• Document all the results in a final report.

4 Case study

4.1 General description

The Military Academy is a public institution of superior education whose main objective is the preparation of future officers to serve in the army and in the national Portuguese guard.

The quartering of Amadora is the place where most of the diversified activities that contribute to the training of cadets are developed, especially in the early years.

Covering an area of approximately 390 220 m^2 of land, the quartering incorporates a significant number of buildings, totaling 32 004 m^2 of deployment area. In Figure 4.1 are shown the main buildings of the quartering, recurring to the computer software “Google Earth”.

Figure 4.1-Representation of the main buildings in the quartering of Amadora.

In the course of its normal activity, the quartering consumes electricity and natural gas to fulfill its energetic needs.

The comparison between the evolution of costs with electrical energy and natural gas can be made by direct observation of the graphs in Figure 4.2 and Figure 4.3.

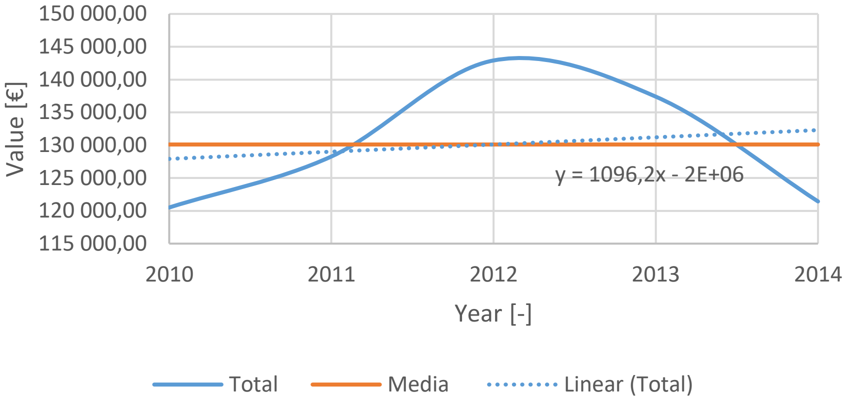

Figure 4.2-Evolution of annual expenditure on electricity in the quartering of Amadora.

Similarly, the water consumption also contributes to a very significant expense. The evolution of the expenses with water is represented in Figure 4.4.

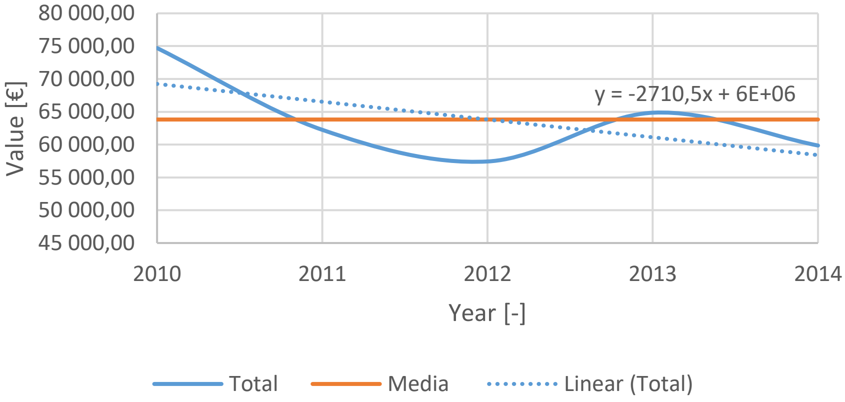

Figure 4.3- Evolution of annual expenditure on natural gas in the quartering of Amadora.

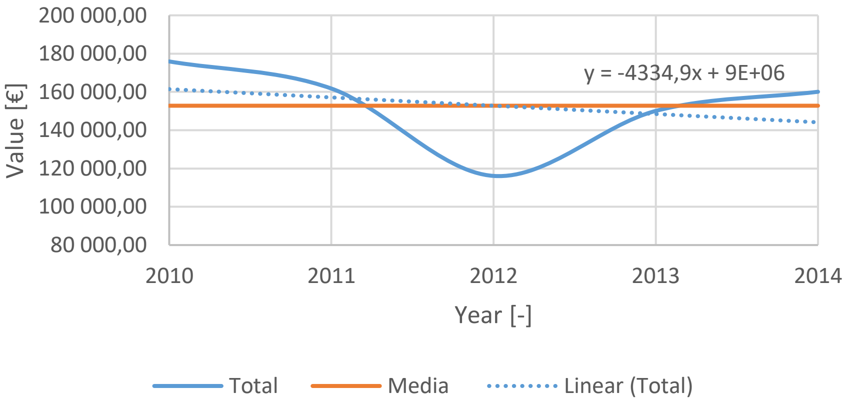

Figure 4.4- Evolution of annual expenditure on water in the quartering of Amadora.

In addition to an approach to the variation in costs of electrical energy, natural gas and water over the past few years, it was also made the analysis of the monthly variation during the year.

The costs mentioned mean a large part of the total charges relating to the operation of the buildings in the quartering, and are necessary to meet the needs of the institution.

4.2 Specific case description

After the general characteristics of the quartering exposed, it was identified a more particular case to study. The chosen building was constructed in 1992 and has the main objective of provide accommodation for the students. This building can be subdivided into three separate bodies, two of them (body 1 and body 3) relating to accommodation and another one (2) concerning a central atrium that separate the first two bodies mentioned.

In this paper, the analysis carried out focuses primarily on body 3, which provides shelter to the students of the first grade and has capacity to accommodate 144 students.

4.3 Life Cycle Cost Analysis

After the collection of the necessary information for a careful calculation of LCC, the methodology described in chapter 3 was applied.

The results of the costs updated to 2015 for all the options included in the analysis are shown in Figure 4.5.

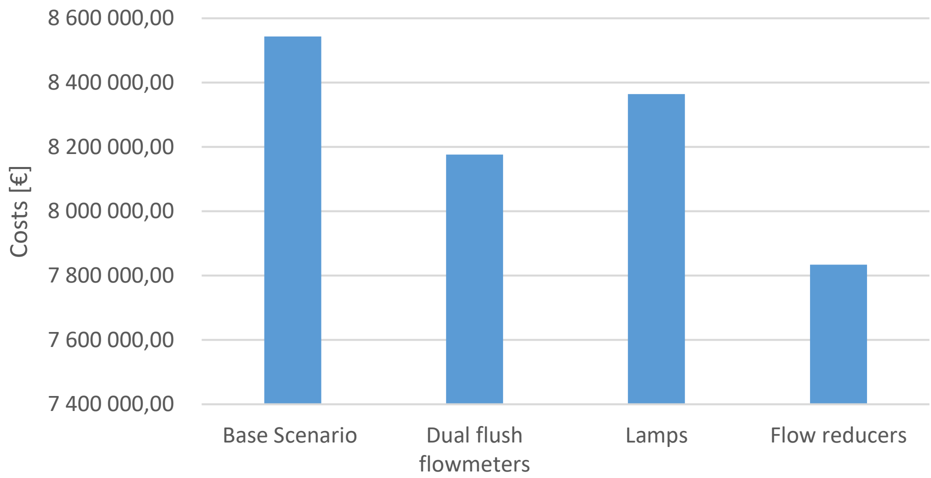

Figure 4.5. Updated costs (2015) of the various options included in de LCC analysis.

It's possible to verify that all the measures in question would be able to reduce the LCC in the order of hundreds of thousands euros. The options that save the most, are the ones related to water consumption.

After the global comparison, it´s presented the analysis of the base scenario, contemplating building maintenance, minor replacements and repairs. In order to estimate more accurately the costs of major repairs it was developed a degradation model to a ceramic façade, that resulted in the next equation (1).

$$S = -27.031 \times JE - 25.648 \times D + 40.019 \times E + 19.929 \times V + 0.026 \times I^2 \qquad (1)$$

The variables of this expression are related to the existence of joints (JE), the dimension of the tiles (D), the type of structure (E), the wind exposure (W) and the age (I).

All the other options proposed were analyzed based on the assumptions defined in the base scenario.

The first analysis was the one referring to the base scenario. The results are displayed in Figure 4.7, Figure 4.8 and Figure 4.9.

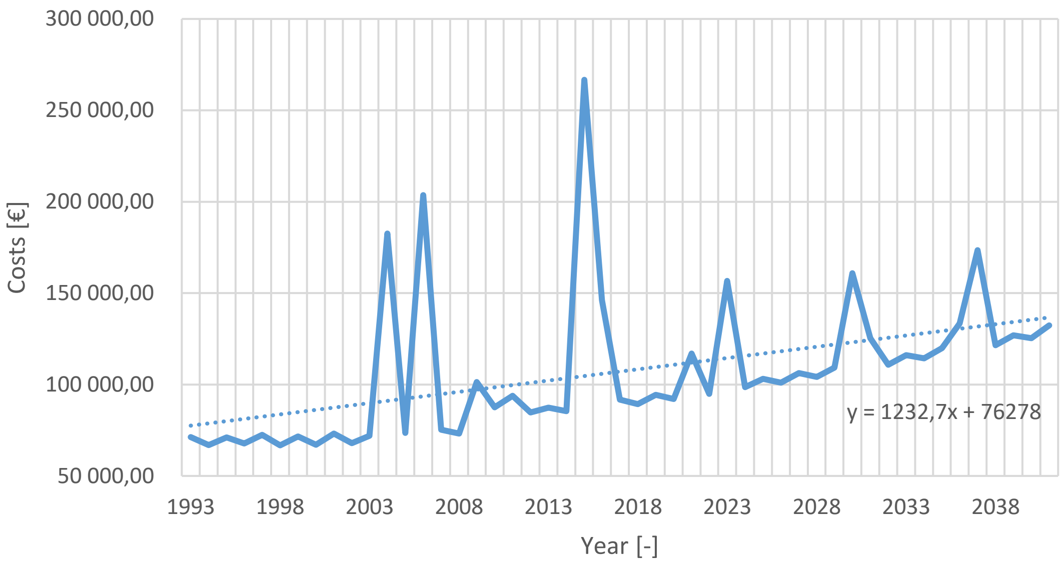

Figure 4.6- Total evolution of building costs.

The evolution of annual costs related to the asset that is being analyzed is represented in Figure 4.6.

In addition to the chart with the total annual costs, it is also presented a chart with the contribution of each type of cost (Figure 4.7).

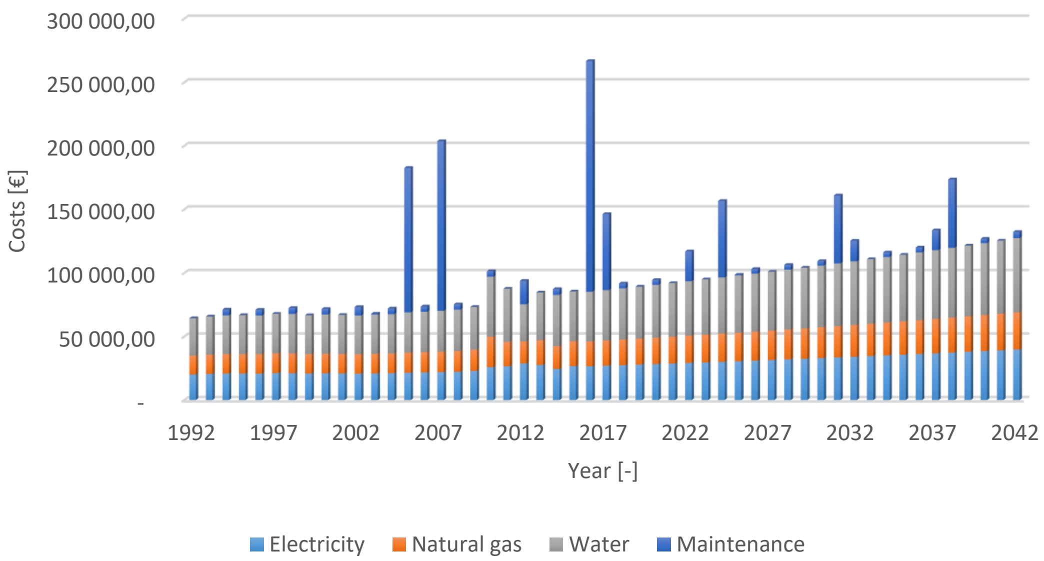

Figure 4.7- Contribution of each partial cost to the total cost.

The exposed chart allows the visualization of the contribute that each type cost gave to the total annual cost.

Still referring to the base scenario, Figure 4.8 presents a chart with a distribution of the total costs.

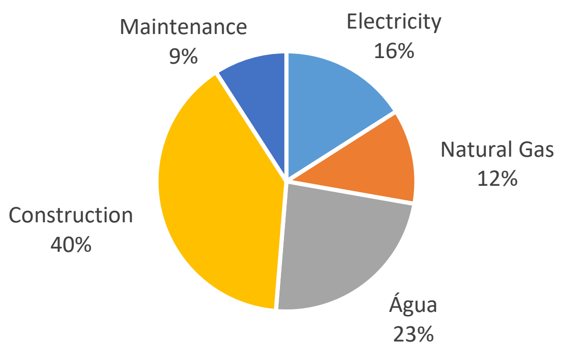

Figure 4.8- Total charges distributed by the different costs considered.

The distribution of total costs, taking into account the entire asset life cycle, show that the construction cost is only 40% of the LCC.

During the methodology were executed some monte carlo simulations, one of which assuming the annual expenses as variables and a triangular probability distribution. The results of this analysis show that the LCC is between 7 120 570€ and 8 795 055 € with a certainty of 80%.

Following the approach made in the base scenario, the other options were also considered.

The first option refers to the replacement of 36 watt T8 lamps for light bulbs with the same physical characteristics, but with lower consumption of electricity (18 Watt). There aren't any additional costs to consider apart from the lamp price because of the equal external characteristics.

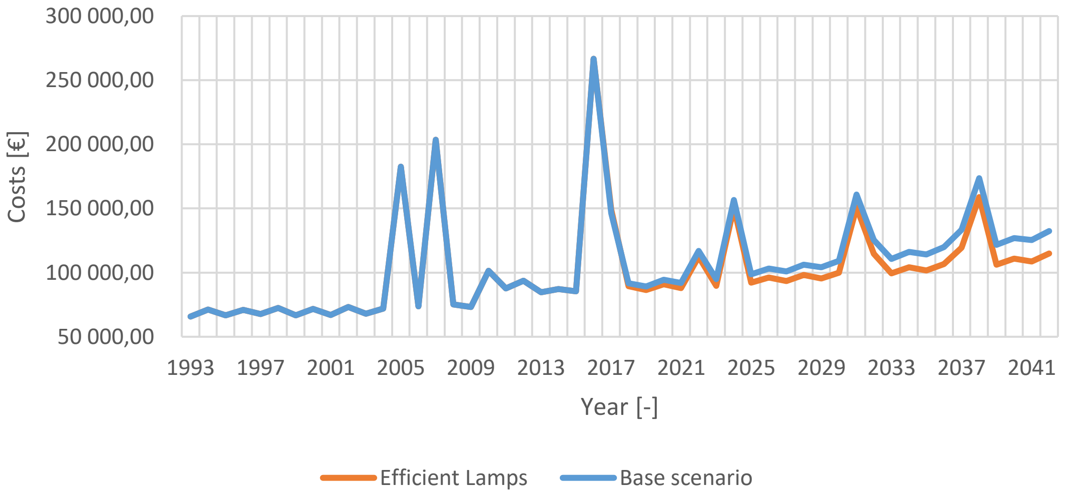

Figure 4.9 - LCC comparison with and without the implementation of efficient light bulbs.

In the Figure 4.9 it is visible the decrease in the total cost, meaning the immediate reduction in monthly electric energy bills and, consequently, in annual charges. On the other hand, the investment amount is absorbed by the remaining costs and becomes almost imperceptible.

After the analysis of the first option, it was analyzed the installation of dual flush flowmeters, which would reduce the discharge with the biggest flow to the minimum number of uses.

A comparison of the LCC with and without the implementation of the measure in analysis is shown in Figure 4.10.

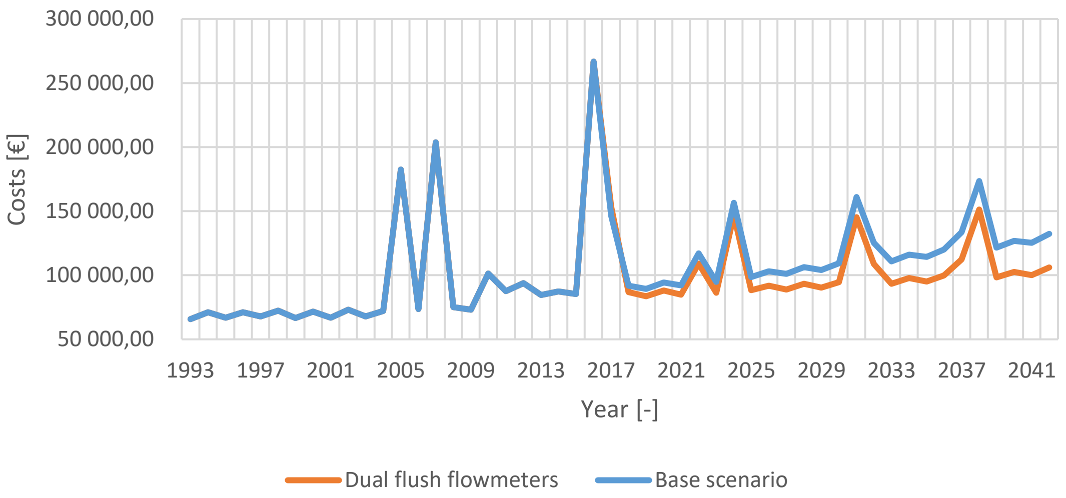

Figure 4.10- LCC comparison with and without the implementation of dual flush flowmeters.

Also with regard to the implementation of dual flush flowmeters, it is concluded that the annual costs with the building would be reduced after the installation. Once again, the installation costs are absorbed in the global analysis. The annual save, in the other hand, is well perceptible

Last but not least, the analysis of the installation of flow reducers. Just like in the other options, it is presented (Figure 4.11) the evolution of the annual costs with and without the implementation of the measure.

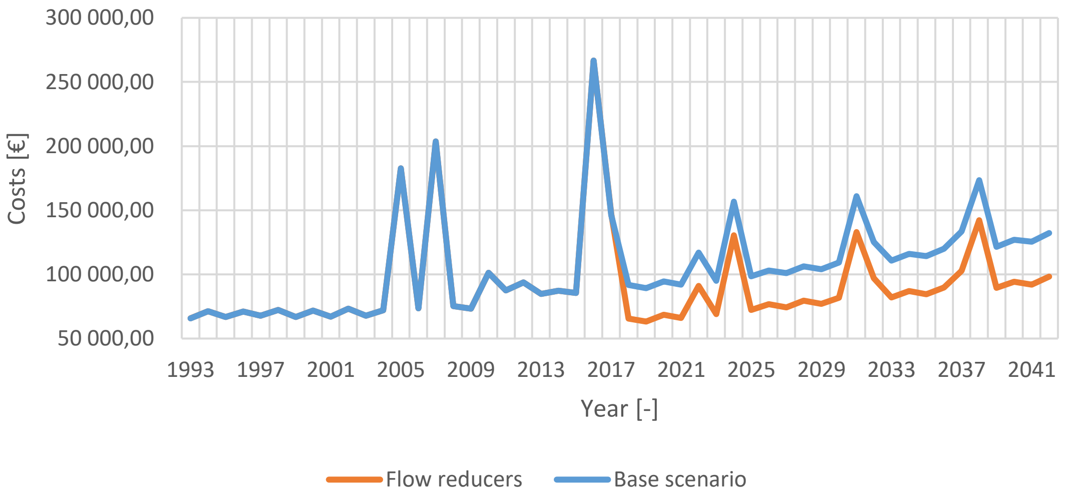

Figure 4.11- LCC comparison with and without the implementation of flow reducers.

This measure is the most advantageous when compared to the other scenarios that were analyzed. The installation of flow reducers is the measure that would provide the biggest save each year. Totally, this measure would save about 709 550 € during the lifecycle of the asset.

The method used to analyze all the options was based on the same assumptions and applied in the same way, so the total value of the savings from the installation of all the options can be added, resulting in a total saving of 1 312 141 €. This value is about 15% of the LCC of the asset, considering the base scenario, and represents about 37% of the construction costs.

5 Conclusions

In Portugal it is still relatively common to evaluate the different construction or intervention options based only on the initial cost. However, the concern for durability and functionality maintenance of the assets has been growing.

In this paper, it is developed a methodology to analyze the LCC of assets. This methodology should provide a tool to make the decisions related to construction easier, and not only based on the initial costs. It can also be a relevant contribute to promote sustainability.

To apply this methodology to the case study, a lot of information was gathered, most of it related to operation and maintenance costs. In order to estimate the costs and frequency of larger interventions, it was developed a degradation model applied to the ceramic façade of the building under analysis.

The results achieved in general, show that the proposed methodology can be applied to buildings in general, and army buildings in particular.

It is concluded that the costs of construction are only 40% of the LCC. The other 60% are distributed by electrical energy consumption, natural gas consumption, water consumption and maintenance. The impact of the construction can be even lower, increasing the analysis period. Doing this wouldn't be completely wrong, because army buildings usually last longer than 50 years.

It is also concluded that the suggested measures result in a significant long term benefit. If all the proposed options were applied, the estimated savings would be about 15% of the LCC. This is a good indicator of the importance of adopting sustainable solutions and a long-term thinking posture.

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