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# Building life cycle applied to refurbishment of a traditional building from Oporto, Portugal



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#### ABSTRACT

Buildings management along with its life cycle is currently an issue that requires a great optimisation considering the high cost associated with the buildings use and due to the operation and maintenance costs. The number of existing buildings needing refurbishment actions justify the need of an intervention model that optimise its service life after the refurbishment process. So, a refurbishment, maintenance and costs planning should be established and guided by value for money principles. The aim of this paper is to analyse the application of Buildings Life Cycle Management (BLCM) to a case study under a refurbishment process, to study the specific solutions and to assess the correspondent service life using the factor method according the ISO 15686 family. With this study, was possible to assess solutions and refurbishment conditions in terms of durability, when compared between the different proposals. In order to improve the case study Building Life Cycle maintenance, in addition, was applied Building Information Modelling (BIM), as BLCM is connected with BIM in order to highlight the importance of their inter-relationship. This study concludes about the most advantageous type of maintenance, how BIM can contributes to BLCM and how can improve maintenance plans.

Thus, this study contributes to highlight the importance of preventive maintenance, to promote its implementation and consequently, to use maintenance plans reducing life cycle cost and increasing materials service life.

#### 1. Introduction

The knowledge to model, analyse, design, maintain, monitor, manage, predict and optimise the life-cycle performance of structures and infrastructures under uncertainty is continually growing. However, the infrastructure or the structure is no longer within desired levels of performance and safety, decisions regarding its systems should be supported by an integrated reliability-based life-cycle multi-objective optimisation framework by considering, among other factors, the likelihood of successful performance and the total expected cost accrued over the entire life cycle [21].

The main objectives of this paper are to analyse the Building life cycle performance assessment, maintenance, monitoring, management and optimisation of construction systems under uncertainty, and its challenges for a specific building, and then connect Building Life Cycle Management (BLCM) and Building Information Modelling (BIM) and highlight the importance of BIM in BLCM.

This study is organised as follow. Firstly, it reviews the related

research about Building Life Cycle Management (BLCM), Life Cycle Cost (LCC), Life Cycle Assessment (LCA), Building Information Modelling (BIM), as they are key concepts used in this study. Based on above, it presents the methodology applied, the study about LCC done and depicts the BIM model developed aiming building life cycle maintenance. Finally, the study ends with conclusions.

#### 2. Building Life Cycle Management

Building Life Cycle Management (BLCM methodology is constituted by planning, design construction, operation and maintain phases of the building during its life cycle. BLCM covers whole processes of construction, using the digital way to create, manage and share the asset Information and based on the integrated virtual building information model and collaboration, is seek to design-construction-management process integration [29]. Building life cycle management is a holistic business concept developed to manage a building and its lifecycle including materials, construction process, quality of workmanship,

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analysis of results, test specifications, environmental component information, quality standards, engineering requirements, changing orders, manufacturing procedures, component suppliers, etc. Saaksvuori, Immonem [30]. To implement the life cycle management, it is very important to know how to create and manage the data and the information correctly [29]. Building life cycle management capabilities include workflow, program management and speed up management operations and it is a collaborative backbone allowing people throughout extended enterprises to work together associated later with Life Cycle Assessment and with Life Cycle Cost [31].

Building life cycle management makes possible to control the whole lifespan of a building and the information connected with it. Efficient building life cycle management enables the owners to compare different solutions, to find the better one and this means that is cheaper and less harmful to all over the life cycle [30]. Therefore, an initial higher investment in quality materials can have a more favourable return over the useful life of the asset, since the overall durability of building depends on the durability of the individual components and materials [27].

Considering that every Building is unique, the need for maintenance, repair and asset renewals varies depending on many factors, including: the quality of construction, design details, exposure conditions and the standard of care given by the owner and their property management team. Notwithstanding the differences between individual buildings, it has been determined that many of them follow a similar pattern as they pass through different stages in their respective lifecycles [7].

#### 2.1. Life cycle stages

Life cycle begin with material manufacturing that includes removal of raw material from earth, transportation to the manufacturing location, manufacture of finished intermediate materials, building product fabrication, packaging and distribution of building products [2].

Building construction sector includes activities relating to construction of new buildings or refurbishment of existent ones, typically including: transportation of materials and products to the construction site, use of power tools and equipment during building construction, on-site fabrication, and energy use for site works. Impacts evaluation of construction fall into this stage in current LCA - Life Cycle Assessment methods [2]. Nevertheless, there are the use and maintenance stage, the longer one, that refers to building operation phase, which includes all activities related to building's use throughout its life cycle. These activities contain maintenance of comfort conditions inside the building, energy consumption, water use, and environmental waste generation. It also takes into account the repair and replacement of building assemblies and systems. Transport and equipment used for repair and replacement in this phase also are considered ([2] and [3]). Finally, there is the end of life, that includes the energy consumed and the environmental waste produced due to building demolition and disposal of materials to landfills sites, including the transport of dismantled building materials, recycling and reuse activities related to demolition waste, depending on the availability of data [3].

Note that reviews of previous LCA studies based the description of building life cycle stages described above. Each life cycle stage may or may not include all the activities described, depending on the scope and details of each project [2].

#### 2.2. Life Cycle Assessment (LCA) and Life Cycle Cost (LCC)

Life Cycle Assessment comprise the assessment of the environmental impact of a product or service throughout its life cycle [6]. The LCA presents 3 variants, depending on the phases of the life cycle that are being studied: Cradle-to-Grave, Cradle-to-Gate and Cradle-to-Cradle [25],

According to ISO [17] and Dixon [6], Life Cycle Cost is the cost of an

asset or its part throughout its life cycle, while fulfilling the performance requirements. These costs calculated by expression (1) [35].

$$LCC = C + PV_{Recurring} - PV_{Residual-value}$$
(1)

Where:

LCC is the life cycle cost, C is the Year 0 of construction costs (hard and soft costs – hard costs refer to labour costs, material and equipment's costs. Soft costs to construction site cost, architectural and engineering fees, pre and post-construction expenses, like movable furniture and equipment).  $PV_{Recurring}$  is the present value of all recurring costs (utilities, maintenance, replacements, service, and others.).  $PV_{Residual-value}$  is the present value of the residual value at the end of the life study (that it is recommended to be 0).

This work will focus on the cost, but is important to recognise that the choice of materials/products for each project has direct and indirect impacts on the environment, as well as in the capital and operational costs. Carrying out LCC and LCA exercise enables project teams to demonstrate that they have considered the environmental and economic impacts of their decisions process and chosen the most appropriate materials/products for its job or task [6]. On building life cycle, the goal for minimizing the building costs and its environmental impacts, either in construction and maintenance stage or end of life is crucial. If it is possible to forecast the budget and maintenance activities in the building design phase, it is also possible to decrease costs over the building service life.

Considering life cycle analysis is appropriate for comparing design alternatives or operations schemes for managers and owners decisionmaking support [23]. So, to develop this study, the understanding of the conceptual methodology behind this process is necessary, and is described in the next section.

#### 2.2.1. Conceptual methodology

In this work, a case study was used, in which, the characterization of a building under refurbishment is made followed by the determination of materials' service life applying the factorial method. This method is a deterministic approach, according to ISO [16], that identifies the influence factors of components' service life, based on the multiplication of these factors by the components' reference service life (RSLC). According to ISO [16], reference service life is a service life known through a particular set of in-use conditions. However, project-specific in-use conditions are usually different from reference in-use conditions, so it is necessary to apply the Factorial Method, multiplying the RSLC by a number of factors, each one reflecting the difference between the reference conditions and in-use conditions [18].

The advantage of Factorial Method is that allows considering the factors that are likely to contribute to variations in service life, therefore applied in this case study. To use this method, is possible to bring together the experience of designers, observations, intentions of managers, and manufacturers. Therefore, this method does not provide an assurance of a service life, but gives an empirical estimation based on the available information [16]. However, this method has disadvantages too: assumes a constant materials degradation rate, which is not real, and the assignment of the same weight to different modifying factors that may have different influence on the durability of a product [24]. Several authors have used this method and modifying factors to estimate the service life of building elements [32]. Lopes [24] applied the factorial method to calculate the service life prediction of facades claddings, Souza [34] to evaluate the life cycle of wooden and concrete poles.

According to ISO [16] expression (2) estimates service life, and the meaning and applicability of the factors are in Table 1.

$$ESLC = RSLC \times factorA \times factorB \times factorC \times factorD \times factorE \times factorF$$
(2)

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