SLPforBMS – Service Life Prediction for a risk-based Building Management System

Summary

The durability of buildings is essential in the quality of life of its users and is a critical component in the social and economic stability of contemporary societies. The interest on service life prediction of buildings and their components arises due to the awareness of society to the need for sustainability, economic factors and the onset of durability problems. Service life prediction is crucial in the management of a vast and ageing building stock, enabling: i) the adoption of more sustainable solutions, adapting the materials' durability to the building's design service life; ii) the optimization of maintenance and rehabilitation actions. Furthermore, it allows evaluating, beyond the initial investment, all costs associated with the use and maintenance phases of the building, which represent 80% of the overall costs.

The use of methodologies supported by service life prediction data is still incipient both at the design/execution and service stages of the buildings. Internationally, there are various normative documents and publications which established values for the estimated service life of various construction elements. However, this information is given as an absolute value, not considering the influence of the buildings characteristics in their degradation. The existing methods address the service life of construction elements in a deterministic way, not considering the uncertainty and variability associated with the degradation agents and their synergy.

This research project intends to develop a building management system of building envelope's elements, including inspection and diagnosis, service life prediction procedures and support decision-making processes in the maintenance/rehabilitation area. The buildings overall performance is intrinsically related to the performance of their components and, in particular to the external envelope that acts as the "skin" of the building, protecting it from the degradation agents.

In the first stage, this project develops an inspection and diagnosis system, characterized by the definition and classification of the four most important variables in pathology: defects, causes, diagnosis techniques and repair techniques, leading to correlation matrices between these four parameters. These systems are validated through extensive fieldwork, using visual inspections, evaluating the degradation condition of the buildings elements (Figure 1). Various authors developed inspection and diagnostic systems for non-structural building elements, following a systematic approach, anchored in knowledge-based inspection, diagnosis and rehabilitation, namely on: i) Flat roofs waterproofing systems; ii) Wall and floors ceramic tiling; iii) Epoxy resin industrial floor coatings; iv) Masonry walls; v) Wood flooring; vi) Wall and floors natural stone cladding; vii) Gypsum plasterboard walls; viii) Pitched roofs cladding; ix) Gypsum plaster coatings; x) Wall renderings; xi) Painted walls; xii) ETICS; and xiii) Window framing.

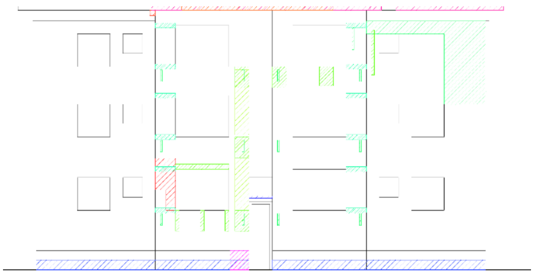

Figure 1. Example of the mapping of defects after the inspection of the case study.

After the definition of this overall system, a computer tool will be created to minimise the subjectivity of the inspections, thus reducing the dependency of the inspector's experience. It is expected that the proposed computerized inspection system has a range set of practical applications: i) Use in inspections; ii) Use in plans of proactive maintenance of buildings; iii) Decision-support in rehabilitation projects; iv) Preparation of devaluation reports of buildings; v) Use for official surveys (pre-intervention, effects of insurance policies; sale/rental); vi) Preparation of final diagnosis report with a standardized structure; and vii) Use as pre-normative basis of standardized inspections for buildings to be subjected to an officially recognized methodology.

The second stage of the project is based on the definition of different service life prediction models, from simple deterministic formulations (single and multiple linear and nonlinear regressions) through stochastic models (Markov chains and logistic regression) and factorial (with deterministic or stochastic approaches) to computational models based on artificial intelligence (artificial neural networks and fuzzy logic), based on the information collected using the inspection and diagnosis system created in the previous stage. Existing methods have some limitations: i) simpler methods generally do not analyse the influence of the characteristics of buildings/elements on their degradation, ignoring the uncertainty associated with this phenomenon; ii) more complex methods are sometimes too complex for unfamiliar users. The

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Leading Institution

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal)

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project intends to clarify all these aspects, providing a decision-making user-friendly support tool to optimize and rationalize the scheduling of maintenance actions.

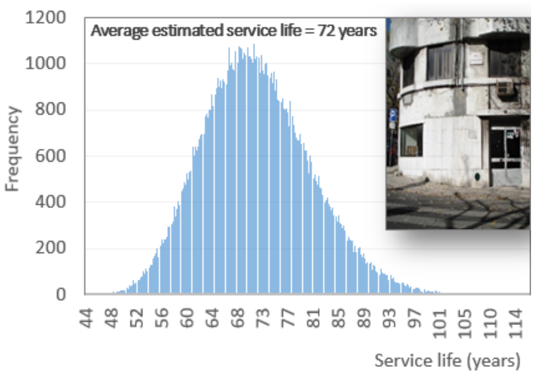

Figure 2. Probability density distribution of the estimated service life of a case study analysed.

Due to the complexity of the methods proposed, computer routines will be implemented to apply the statistical methods for the service life prediction methods of building envelope's elements. The project intends to create a user-friendly software capable of estimating the service life of a wide range of building envelope's elements (coatings and claddings). This software is an internationally innovative tool, allowing the user (planner, designer, constructor, engineer, architect, manager, insurance company) to predict the service life of a building element based on a set of simple steps: i) Choose the case study; ii) Select in the program the envelope's element to be analysed; iii) Decide on the model of service life prediction (considering the intended output's preciseness and complexity); iv) Define the maximum degradation level that establishes the end of service life of the elements (depending on the users' comfort target level. The software will be assisted using a number of interactive tools that provided the user with various indications and recommendations that will facilitate the program's implementation, such as: i) Illustrative examples of different degradation levels associated with the detected pathology and according to the envelope's elements considered; ii) Functional description, advantages, limitations and type of results obtained by each service life prediction method implemented; iii) A step-by-step guide concerning the application of each method. The results obtained through the program will be easy to interpret and can be used directly in service life prediction of the elements without the need to resort to further mathematical modelling. Reading the program's output will also be assisted by the software itself. In the next task a customer support manual that facilitates the application of the software created is defined.

The software developed in this project can be used as decision support tool for manufacturers and materials prescribers, designers, contractors, developers and insurance companies, as it allows stochastically considering the risk associated with failure of the envelope's elements. The software created in this project will be submitted for "Patent for computer-implemented inventions".

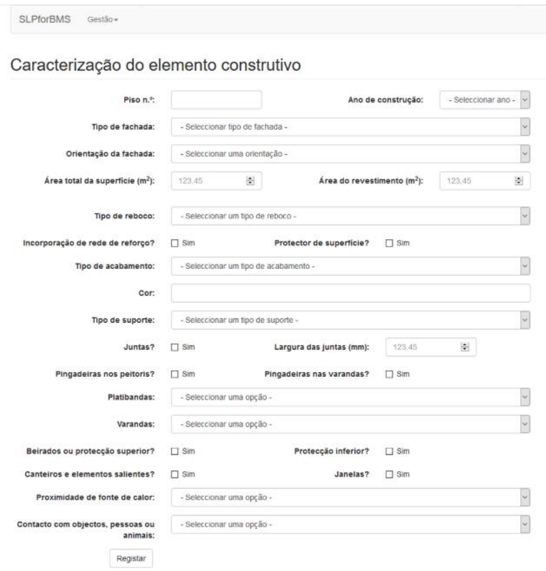

Figure 3. Preliminary interface of the software homepage.

The research team has a considerable experience within the scope of the project, with two books and over 50 papers published in international journal in the fields of expert knowledge systems applied to the maintenance of built heritage and in service life prediction. The main lines of innovation of this project are: i) the models are based on advanced statistical tools, with an estimated service life given by a characteristic value associated with a probabilistic distribution; ii) the models are based on artificial intelligence, capable of generalizing for new case studies; iii) the models are created with information based on a specialized data acquisition system that is constantly fed; iv) the models are adapted to the quality and quantity of available data; v) the output of the models are adjusted to user's needs (prescribers, designers, contractors, maintenance managers, insurance companies); vi) it is possible to quantify/simulate the influence of design, exposure and use conditions on the life cycle of the building envelope's elements.