An interoperable ICT tool for asset and maintenance management - Advances in research -

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ABSTRACT

Asset and maintenance management needs to store and use much information about the behaviour over time of different building materials, products and components. Service life planning and data capitalization from facility management are only the first steps for an efficient asset management because it is necessary to develop specific ICT tools for life cycle data use and sharing.

Managing information related with actual maintenance works and inspection activity (condition assessment) allow handling Building Information Systems and this is fundamental in order to fit the reliability and service life evaluations for maintenance planning.

For this reason, an ongoing research activity is developing some methods and tools for Service Life Planning and Management, which can be easily integrated by maintenance data to be used during planning, design, facility and maintenance activities.

The aim is to develop an interoperable Life Cycle Management System (LCMS) platform where this kind of data are available and where different stakeholders can store and share information about building and constructed assets.

The interoperable LCMS platform can be then used on actual maintenance works management to demonstrate the benefit as for economic (Life Cycle Costs) and environmental achievements (Life Cycle Assessment).

This operation has been done according to the international standard for service life planning of building and constructed asset procedures ISO 15686, in particular in conformity with the fifth part on Life-cycle Costing, which allows a cost analysis of the entire building life cycle (maintenance included).

Eventually, this ICT-tool is being developed using the standard IFC (Industrial Foundation Classes) of IAI (International Alliance for Interoperability) to define Building Information Models (BIM).

In particular, interoperability will be guarantee by sharing file .ifcxml and therefore using eXtensible Mark-up Language (XML).

Service life data, maintenance information, costs and each parameter for sustainability have in fact to be matched with Building Information Models attributes, upgrading BIM objects themselves in case of lack of some attributes.

This database will be accessible online from a web platform, which is thought to become an interactive footbridge among different stakeholders. As the quantity of collected information will be huge, there are different views of the database according to the stakeholder profile: the aim is to facilitate its use, filtering only useful data for the considered stakeholder, but leaving the possibility to search, visualize and, possibly, modify any other information of the database.

Hereafter the advances in research to structure this database and to enhance existing methods and tools for Life Cycle management are described.

KEYWORDS: Maintenance, facility management, database, ICT, interoperability

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1 INTRODUCTION

The chief objective of this project is to develop an open and interoperable database for asset and maintenance management, designed to store objects with different level of complexity (from simple products to entire construction works) which can be reciprocally linked and completed with an articulated data set.
The database is structured in order to contain Reference Service Life data, with a transparent indication of each data source, but also the necessary parameters and procedures to estimate SL in different contest conditions. To do that, a proper section of the database is dedicated to keep data of the specific context, such as dimensions, volumes, surfaces, costs, fulfilled maintenance interventions, etc.
Moreover, the database contains environmental parameters, both those indicated in UNI EN 15804:2012 and those used by sustainability certification such as LEED, BREEAM, ITACA, Casaclima Nature, HQE and Minergie–ECO. Thanks to this data intersection within the same sharing tool, the aim is to provide efficiently the possibility to evaluate LCA and to calculate reliable LCC, according to the specific design maintenance strategy.

The first step of this project was, therefore, to fathom existing databases (national and international ones) which actually are collecting environmental impact factors, Service Life data and Life Cycle costs estimation, in order to individualize every important parameter to be stored at different level of object complexity (also according to reference standards). The second step was to define dataset structure and properties, considering that the database has to be comply with UNI 11337:2009 and, therefore, with a classification and coding system which must avoid unambiguous individualization of each product, layer, component, activity, work and environment. According to this, it was important to choose the most suitable ICT tools, evaluating if it was better to structure a relational database or not, completed by different modulus (SW/web services) to plan or manage works and developed to fulfil needs of stakeholders such as Designers, Maintenance Planners, Real Estate and Facility Managers. Such tools are focused on one side on Service Life and maintenance issues, developing the knowledge on Service Life Prediction Methods to plan maintenance and inspection of works. On the other side, such tools allow economic planning considering Life Cycle Costs and sustainability evaluation for Life Cycle Assessment (LCA).

The proposed methods and tools, therefore, bring out advances in finalizing the developed knowledge on Service Life Planning and Management, to make it available to users involved in maintenance: this **Life Cycle Management System platform** needs relevant advances in Building Components Service Life data collection and appraisal methods to support users in Service Life Planning. With this aim, the implementation of Service Life prediction methods needs to undertake a set of experimental accelerated tests in order to finalize and standardize data collection procedure. In this way, it is possible to:

- build up a Reference Service Life information platform with an agreed European structure and guidance rules for the use at regional level;
- define Reference Service Life evaluation methods based on laboratory accelerated ageing;
- capitalize Reference Service Life Data from all sources thanks to the platform.

The development of this interoperable LMS prototype has been then applied on actual maintenance works management in order to verify results and to demonstrate the benefit as for economic (life Cycle Costs) and environmental achievements (Life Cycle Assessment). This operation was done according to the international standard for service life planning of building and constructed asset procedures ISO 15686, in particular in conformity with the fifth part on Life-cycle Costing, which allows a cost analysis of the entire building life cycle, including maintenance.

The use of eXtensible Mark-up Language (XML), with a standardized formatting (ifcXML) allows defining other mark-up languages, which can be immediate read by different software and tools. Even the web platform will use xml, because it offers a higher flexibility than HTML in the definition of tags and it gives the possibility to be extended according to future requirements. One of the propulsive ideas, in fact, is that, without any specific ICT tool to allow an access ubiquity to information about life-cycle, service life management and planning cannot be actually undertaken.

2 METHODS AND TOOLS FOR SERVICE LIFE PLANNING AND MANAGEMENT: ADVANCES IN RESEARCH

At present, existing methods for SL prediction are usually not applied because too complex or too unreliable whereas existing databases are full of blanks and most of the times data source is not clear. The lack of effectively usable and reliable methods, together with the necessity of creating an open data collecting and sharing tool, bring to the impossibility of obtaining trustworthy LCC and LCA evaluations.

Moreover, the recent Italian standard UNI 11337:2009 introduced a new and standardized approach for codifying each construction object, from the simple product to the entire work (independently from its complexity). Thanks to the use of ID code, it is possible to store correctly the set of data referring to that object, using also the potentialities of Building Information Modelling.

Consequently, it is fundamental not only to improve existing methods for SL planning but also to create innovative tools for data sharing, where data are linked to a unique code and, through the use of IFC 2x4 standards, represented as BIM objects.

2.1 Methods

The chosen road for Service life planning is well traced: the first two parts of ISO 15686 give all the necessary indications in order to face the matter and to solve it through an integrated methodological and experimental approach. According to ISO 15686 “Buildings and constructed assets. Service life planning”, which provides at international level the general framework about service life’s appraisal and management, UNI 11156:2006 defines precisely the duration or service life of a component and describes a procedure for its evaluation, considering a minimal maintenance level (the ordinary maintenance operations).

The appraisal of Service Life finds in the “Reference Service Life” value an input datum: this duration is obtained experimentally through ageing tests under the action of stressing agents. The term “reference” is used to indicate the boundary conditions that are assumed.

In order to give scientific strength to collected data, it is therefore necessary to finalize the standard approach to gather SL data from laboratory evaluations. The proposed project, in fact, also evaluated the general applicability and efficacy of a pioneering procedure to define accelerated ageing cycles for reference service life evaluation. In few words, this innovative method is based on a statistical treatment of climatic data and on the individualization of the frequency of critical weather conditions for the tested building component or material. The frequency allows defining the accelerated ageing cycle to set in climatic chambers for lab durability tests [Daniotti *et al.* 2008]. To do that, it was therefore important to develop new lab tests which could validate the applicability of the proposed accelerated ageing cycle to different climatic conditions, even extreme ones [Lupica Spagnolo 2009].

These laboratory-based methods include short-term accelerated testing procedures, property tests and long-term experimental set-ups. As a result, test procedures and data can be correlated with in-service conditions of components and materials providing a guiding way to use the platform for Service Life prediction and management, which can be taken as reference for the update of ISO 15686-6:2004.

The outcomes of reference service life appraisals, according to the proposed procedure, can then be elaborated in order to estimate Service Life in design condition, using one of the methodologies described in ISO 15686-2:2012, which mainly differentiates for complexity (and therefore for the quantity of information and resources necessary for their application).

In analysing the most suitable methodology to adopt, it is necessary to underline that the official appearance on ISO 15686 series of Factor method created some unrest. In reality, over recent years a

debate at international level opened on the possibility of an effective use of methods based on factors in Service Life evaluation: such methods, in fact, had already been adopted in building field in Germany and in Japan. In particular, in the short version of the Principal Guides published in English, a method to pass from the Standard Service Life - equivalent to the RSL defined in the ISO - to the ESL through factors very similar to those introduced in Europe was developed.
As an example, in a study about service life planning of a multifamily building built in Gavle, Sweden, in 1999, the ISO 15686-1 procedure was applied. Service Life planning was integrated in the building's design and it was followed from the design phase to the construction one. Only few tests were undertaken to simulate all the different effects on building component in real conditions. The accuracy of the estimated service life suffers from this fact. If the aim is to find a precise value, it is obvious that it cannot be reached, while if it is to improve the general situation in the planning of service life, then Factor method can be a tool aimed to improve service life estimation. However, this study shows that such method does not improve it. This opinion is justified by the following points:

- uncertainty about RSL and factors values: the factorial formula presents the reference value (RSL) and corrective factors from A to G, so if the reference value cannot be carefully determined, it's not appropriated to correct such value with a series of uncertain factors;
- uncertainty on the effect of the combination of the factors: the concatenation of the various effects turns out to be of difficult appraisal and needs a study extremely deepened of all the possible degradation phenomena of those technologies taken into consideration.

At international level, the term "Lifetime Engineering" is intended as the harmonized group of the procedures thought in order to solve the asynchrony between designed performances and real ones, over time, in a building product. "Lifetime Engineering" comprises:

- lifetime investment planning and decision-making;
- integrated lifetime design;
- integrated lifetime construction;
- integrated lifetime management;
- modernization, reuse, recycling and disposal;
- integrated lifetime environmental impact assessment and minimization.

In particular the "Integrated Lifetime management"[3] foresees, besides maintenance planning, the continuous appraisal of performances' levels (condition assessment), the predictive performances modeling and the management of maintenance alternatives based on the analysis of technical elements' reliability and durability (*decision making reliability and durability based*).
From these considerations it is clear therefore that if we want to continue to speak about Service Life Prediction finalized to the optimization of maintenance interventions and to the cost reduction of buildings' life-cycle (LCC), it is necessary to implement the today available estimating methods and tools because their application is operatively too difficult and, economically, still not favorable.
This research has the aim to contribute operatively but also methodologically for an effective application of such existing methods, through:

- the creation of a database which collects all currently available Reference Service Life;
- the definition of evaluation grids in order to drive the designer in the application of Factor method, limiting the subjectivity of the method itself (overcoming, therefore, the critics that such methodology moves, but maintaining its simplicity of use);
- the experimental activity in laboratory for the determination of Reference Service Life, input data for estimation methods;
- the experimentation of the actual applicability of Factor method for Service Life assessment and the method for reliability's appraisal through documents as the performance specifications and the maintenance plan, with also a critical analysis of real designers' difficulties.

Through these implementations, therefore, it is possible to predict Service Life and exploit such information for a better design and an optimized maintenance planning. Each of these activities is closely connected to the others, using as input data the output data from the previous ring of the chain

[3] **EU-Growth Research Programme.** Thematic Network: *LIFETIME: "Lifetime Engineering of* Building and Civil Infrastructures".

and supplying itself the input for the successive one. For this reason, it is indispensable to move on each of these fronts, highlighting troubles and proposing further methodologies to resolve them.

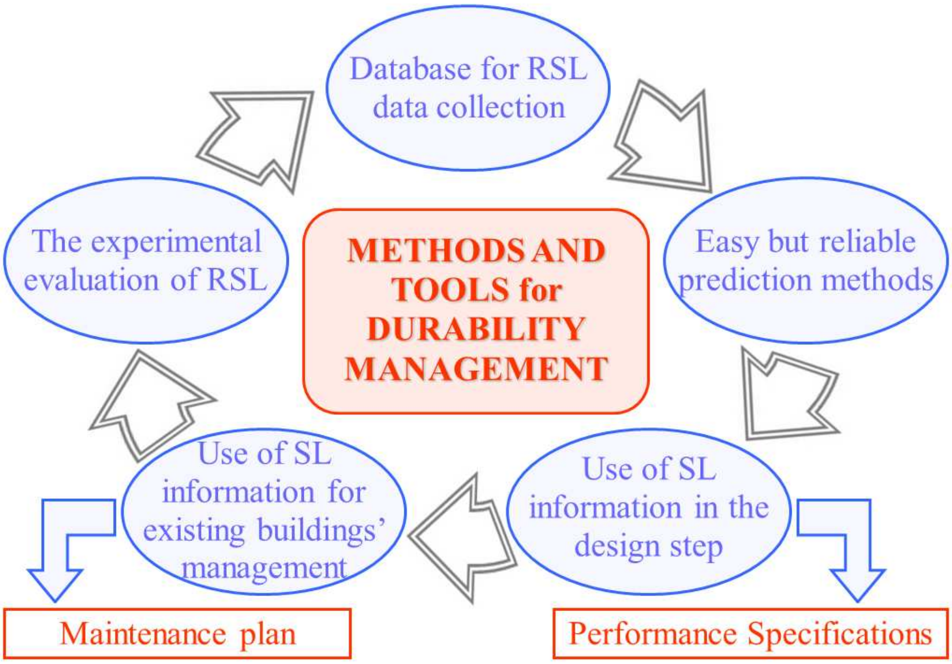

Figure 1 - "Chain" for the management of durability.

The implementation of each single ring of the chain for Service Life prediction wants therefore to make usable the methodology proposed from ISO 15686 for a real durability assessment.

Manufacturers of building and construction products are usually in possession of considerable knowledge concerning Service Life and durability of their products. However, such information is only occasionally publicly shared, typically in product declarations, other documents, company websites and/or databases. The use of this International Standard is expected to motivate manufacturers to compile their knowledge and provide Service Life data following what guidelines and requirements state [ISO 15686-8:2008]. That is why it is necessary to create a hub for Service Life management systems, where needed information is properly stored and shared.

2.2 Tools

Tools for service life prediction gather input data from a series of different information sources, as foreseen in ISO 15686. Specific tools manage information related to current maintenance and inspection activities, so to obtain a feedback on management systems for building information, useful for the appraisal of building components service life and reliability.

In Europe, the only currently available database (with information about materials' standard duration) comes from England: it is called Construction Durability Database and it contains a wide number of elements and technical sub-elements. Such a database was commissioned by an insurance society (Housing Association Property Mutual) and realized thanks to the studies carried out by BRE (Building Research Establishment) that worked on 15 years of collection data and of experimentations from the Building Group Performance and from other analogous organizations.
Besides the standard duration, this database provides some corrections to apply in order to consider other elements that can increase or decrease reference service life.
Through the analysis of the necessary information to allow designers evaluating duration and planning maintenance, CSTB (the French Scientific and Technical Centre for the Building Industry)

and Politecnico di Milano started structuring an international RSL database [Hans et al. 2008]; such a database contains some input data necessary to ICT tools for service life management.
Thanks to the experimental tests Politecnico contributed not only to RSL definition, but also to create some grids for the application of Factor method, considering moreover the elaborations on statistical basis lead on the climatic agents, necessary for accelerated ageing cycle definition. As a consequence, the database for RSL collection became necessary not only for the convergence of all the information coming from the experimental researches, but also in order to constitute an indispensable tool for the application of existing methods for SLP (ISO 15686-2 and UNI 11156-3) and in particular of Factor method.

Starting from the expertise in developing the Reference Service Life database, Politecnico di Milano has been structuring a new and wider platform for data collection and exchange, where Service Life data and "Factor methods referring grids" about opaque vertical and horizontal enclosures taking into consideration different climatic contexts are already stored. This platform contains also a tool for durability evaluation, which allows exploiting the developed Factor methods grids to evaluate Service Life also for technical solutions with design conditions different from reference ones: the user will be able to obtain ESL just selecting the real factors configuration.
The information of Estimated Service life, elaborated by means of the application of an enhanced Factor method, which guides the user in the choice of the corrected multiplicative factors and in the obtaining of a sufficiently reliable value of ESL, is eventually associated to a BIM object in order to make information usable also by interoperable software.

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