SERVICE LIFE DATA IN LIFE CYCLE MANAGEMENT OF BUILDING

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ABSTRACT

A sustainable building process needs to address service life of building and of its components since the first stage of design. Service life data are needed to perform a reliable Life Cycle Assessment, to compare different design solutions using the LCC analysis, to forecast maintenance costs, etc. It is therefore necessary to identify the most suitable tools to manage life cycle and the required data (types and sources) for a Life Cycle Management process.
A LCM process can be divided into sub-processes (inventory registration, condition survey, service life performance analysis, maintenance analysis, maintenance optimization, maintenance planning). Some of these sub-processes are more data demanding than others, but they all need different data, according to the design stage. If the LCM is undertaken in an early phase of the design process, then some rough data and easy to use service life prediction method will be useful, otherwise, if the design process is in an advanced phase, statistically accurate data and more precise service life prediction tools will have to be adopted.
This paper will show the first results of a research undertaken at the Politecnico di Milano, aimed to identify the needed service life data in different design stages and the most suitable service life prediction methods in order to design sustainable buildings.
Some data sources are quite rounded up or derive from sources that are not interested in technical service life as, for example, insurance data, so it is necessary to know when they can be used or which is the acceptable error in each different design phase. On the other side when planning maintenance one may need to know building components' performances decay over time and such complex data are not easy to be found.
If we look at service life prediction methods we can find the same problems: each SLP method is characterized by a different complexity, both in input data and in the mathematical model, and a different reliability of results. In this case this papers will help designers in choosing the most appropriate SLP method according to the design phase and the required reliability of results.

1.- Introduction

The evaluation of durability is based on the study about service life and reliability (time in which the required performances maintain spontaneously above the required levels and probability to reach that time) and on the acquisition of the knowledge about performance decay (information about time and way of its happening). This allows organizing the design and the planning of necessary maintenance works.
Service Life prediction for an optimized maintenance planning (Fig. 1) is therefore useful for the life-cycle management and for determining life cycle costs, but also to guarantee a sustainable constructive process: the knowledge about building components' durability (duration and reliability) is fundamental in order to operate a choice based on the sustainability of their employment according to the differentiated obsolescence of building's parts and, in particular, in order to decide the best

maintenance strategy to be used: the reliability evaluation of the estimated service life allows adopting the most suitable maintenance strategy, while the complementary estimated value for reliability gives information about the risk of failures during the building component's Service Life.

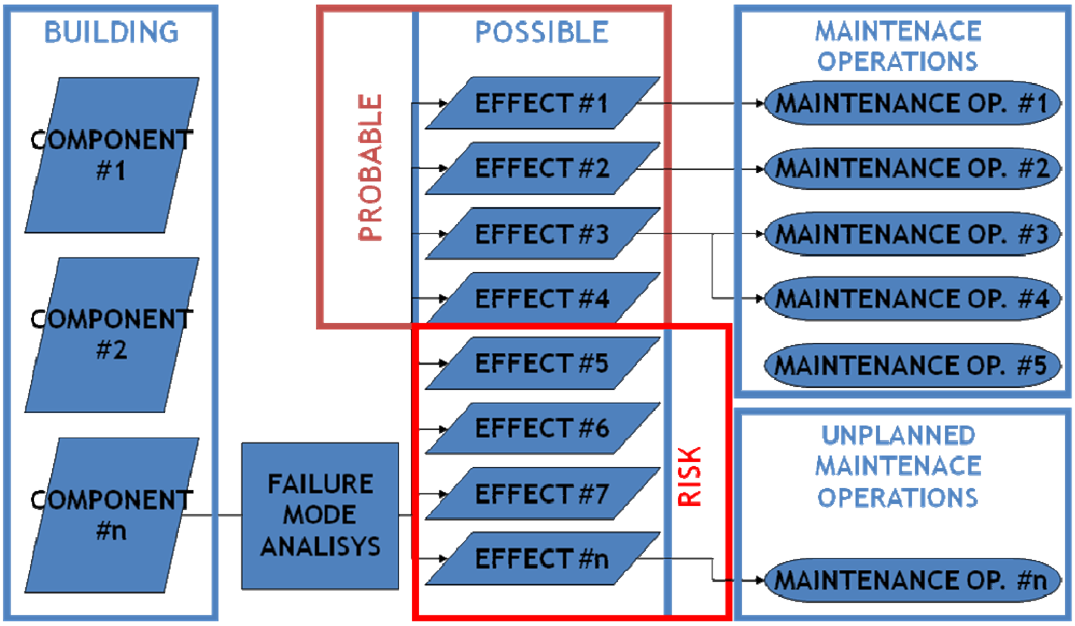

Fig. 1 - The process of identifying maintenance operations on a building component

In order to allow such maintenance design, based on Service Life prediction, it is necessary therefore to implement existing methods and tools.
Service life and modalities of performance decay constitute the basic acquaintances to plan maintenance activities necessary to the conservation over time of buildings.
The knowledge of the failure rate course at the beginning and at the end of service life permits, in particular, to plan predictive threshold interventions at the mean value of service life. Therefore, the information about building component's duration turns out to be an essential input data for the maintenance design. Considering this, the experimental and methodological research activity on durability involves important effects in facility management, that is why the proposed database for Service Life planning contains explicitly the information about maintenance frequency and it is structured in order to make collected data immediately usable during LCM.

2.- The importance of building materials and components data collection

The necessary information to correctly choose building materials and components comes essentially from two sources:

- data provided by manufacturers, which are usually more commercial than technical;
- experience gained from the observation of building products' behaviour over time which allows stakeholders such as designers, installers and maintainers accumulating a precious know-how they are not always available to share;
- laboratory experimentation.

Although information papers (technical and nontechnical ones) can provide enough data for a correct evaluation and choice of construction products, such data are often scattered inside not standardized documents, which can require long and difficult interpretations. That is the reason why the comparison among analogous materials made by different manufactures can be very complex and many times impossible, so that the less scrupulous operator uses to choose the same materials and components, without a careful evaluation about their employment. The predisposition of standardized technical information should favour a better knowledge of building products and, as a consequence, a higher quality level of building designs.

Moreover, it is also important to take into account different required performance levels according to the intended use: for instance, private and public buildings can require different performance levels which can vary significantly. That is why, for example, the hotel field differs from the common residential field for many performance requirements or why flooring materials, even if they have to satisfy "usual" needs (users' safety, comfort, usability, etc.) generally express different performance levels.

Among such information, service life and reliability data should be provided because the experience shows the existence of an unavoidable phenomenon of performance decay over time, which has to be taken into account. When such performances do not reach anymore the required acceptable level for the technological system, it is necessary to activate suitable maintenance interventions in order to restore their intensity. Thanks to the durability assessment it is possible the acknowledgment of a technical element's attitude to supply, over an established time and with a programmed intensity, the initial technological performances. This, also, for the following reasons:

- **for legislative impositions:** standards such as the Italian law n. 109/94 and the following decree (which has the force of law) n. 163/06 have obliged to draw up "performance specifications documents" and maintenance plans for every public works' design; as the maintenance plan provides the scheduled maintenance activities in order to maintain over time the wanted functionalities, characteristics of quality, efficiency and economic value, the necessity to know Service Life turns out to be evident;
- **for economic reasons:** the value of built works has assumed more and more importance in the conscience of users/owners (both public and private); the life-cycle management process turns out to be of fundamental importance in the economic evaluation of every single partnership, especially now that, in Italy, it becomes more and more diffused the use of alternative tools for finding the necessary funding for public works, such as the project financing or the Public-Private Partnership;
- **for environmental reasons:** the shortage of materials and the progressive impoverishment of fossil energetic resources have pushed the building field to face such a thematic; nevertheless also the problem of buildings' environmental impact has assumed big importance in the last few years, bringing towards a collective sensitization for esteeming environmental impacts of realized works (see ISO 14040 [1] and ISO 14044 [2]).

3.- The accuracy of data in relation to the service life prediction method

ISO 15686-1 [3] provides a service life prediction method, the factor method. Scientific literature gives us many other methods which can be classified, according to CIB W80 - RILEM 175 SLM, either as engineering methods, for example the evolved factor method where each factor of the ESL equation may be represented by a statistical distribution (see Moser [4] or Re Cecconi [5]), or as stochastic methods, where inputs are statistical distributions and the relation between inputs and estimated service life is stochastic.

Each of these methods requires a different input data accuracy: while the factor method can use deterministic data both for RSL and for factors, so that data accuracy may be not so important, engineering and stochastic methods relay more on input data exactness. Nevertheless it has to be considered that factor method and any engineering method based on it, i.e. the evolved factor method, are very sensitive to errors in input data. For example a 5% error made on every factor may lead to a 30% to 40% error in the ESL as shown Table 1.

		ESL	RSL	A	B	C	D	E	F	G
BASE -5%	-30%	6.98337	10	0.95	0.95	0.95	0.95	0.95	0.95	0.95
BASE		10	10	1	1	1	1	1	1	1
BASE +5%	41%	14.071	10	1.05	1.05	1.05	1.05	1.05	1.05	1.05

Table 1 - Factor method sensitivity

The same will happen if an evolved factor method is used: for example if a triangular distribution[1] is chosen for each factor and three components with the same RSL and most probable value are chosen in order to differ because one has the minimum value equal to the most probable (called DxShift, Fig. 3), one has the maximum value equal to the most probable (called SxShift, Fig. 2), and the last has the minimum value equal to 0.8, the most probable equal to 1 and the maximum value equal to 1.2 (called C, Fig. 4).

$$\begin{array}{l} SxShift \rightarrow A_{\min} = B_{\min} = C_{\min} = D_{\min} = E_{\min} = F_{\min} = G_{\min} = 0.8 \\ SxShift \rightarrow A_{mostprobable} = B_{mostprobable} = ... = G_{mostprobable} = 1 \\ SxShift \rightarrow A_{\max} = B_{\max} = ... = G_{\max} = 1 \end{array}$$

Fig. 2 - Input factor for ShShift component

$$\begin{array}{l} DxShift \rightarrow A_{\min} = B_{\min} = C_{\min} = D_{\min} = E_{\min} = F_{\min} = G_{\min} = 1 \\ DxShift \rightarrow A_{mostprobable} = B_{mostprobable} = ... = G_{mostprobable} = 1 \\ DxShift \rightarrow A_{\max} = B_{\max} = ... = G_{\max} = 1.2 \end{array}$$

Fig. 3 - Input factor for DxShift component

$$\begin{array}{l} DxShift \rightarrow A_{\min} = B_{\min} = C_{\min} = D_{\min} = E_{\min} = F_{\min} = G_{\min} = 1 \\ DxShift \rightarrow A_{mostprobable} = B_{mostprobable} = ... = G_{mostprobable} = 1 \\ DxShift \rightarrow A_{\max} = B_{\max} = ... = G_{\max} = 1.2 \end{array}$$

Fig. 4 - Input factor for C component

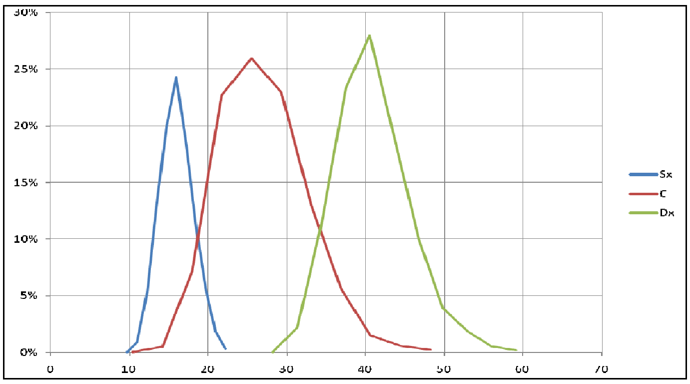

Fig. 5 - ESL of the adopted components computed with the Monte Carlo method

[1] A triangular distribution is characterized by three value: minimum maximum and most probable.

In this case, using the Monte Carlo method, it is possible to compute the ESL when the RSL is 25 years and the results are shown in Fig. 5. The ESL mean of the SxShift component differs from the one of the C component by ten years (38%) and the ESL mean of the DxShift component by 14 years (57%). These great differences are due only to small differences in the statistical distribution of the factors because RSL and most probable value of factors are the same for the three components.

4.- The accuracy of data in relation to the objective of service life prediction

The accuracy of data to be taken from the proposed SLP Platform database depends on the methods used to estimate service life (fig. 6) and on the service life prediction objective. In the early design stage any life cycle evaluation will be based on bigger approximations than the one made using RSL and deterministic data in a factor method estimation.

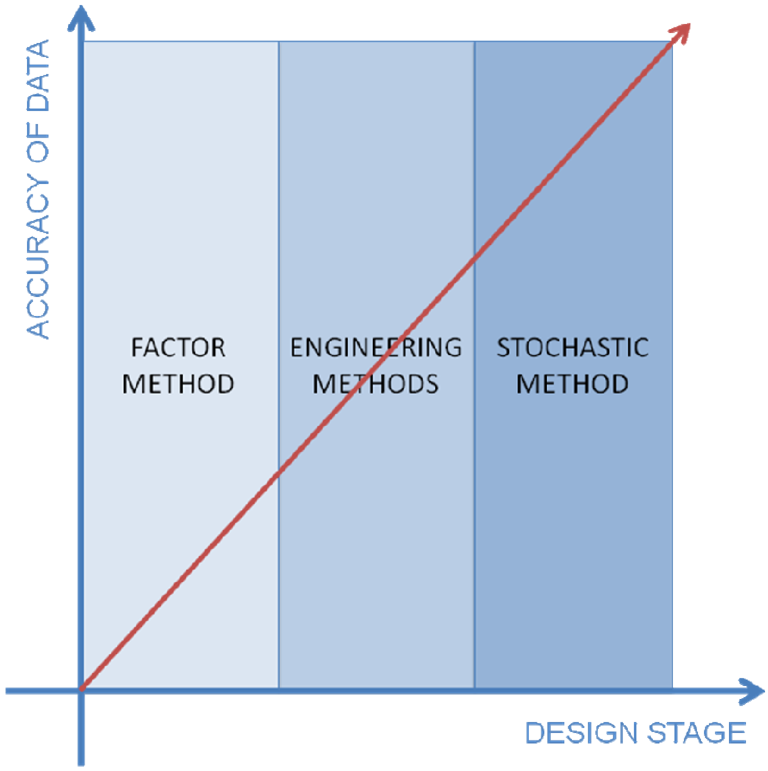

Fig. 6 - Relationship among the design stage, the SLP method and the accuracy of input data required

For instance, in order to forecast energy costs over the life cycle, oil and electric power costs are more rounded up than any value of RSL. In the early design stage it is therefore possible to use RSL data and deterministic factor from SLP platform to estimate service life of building components.

On the other hand, when a more reliable service life estimation is needed, i.e. when a maintenance budget has to be prepared or when planning maintenance of critical components, SLP platform may give RSL data with the required level of accuracy. For example statistical distribution of RSL will be given in order to be used in engineering or stochastic service life prediction methods when the ESL is used in planning maintenance operations (see fig. 7 where time and cost uncertainty in maintenance planning are highlighted).

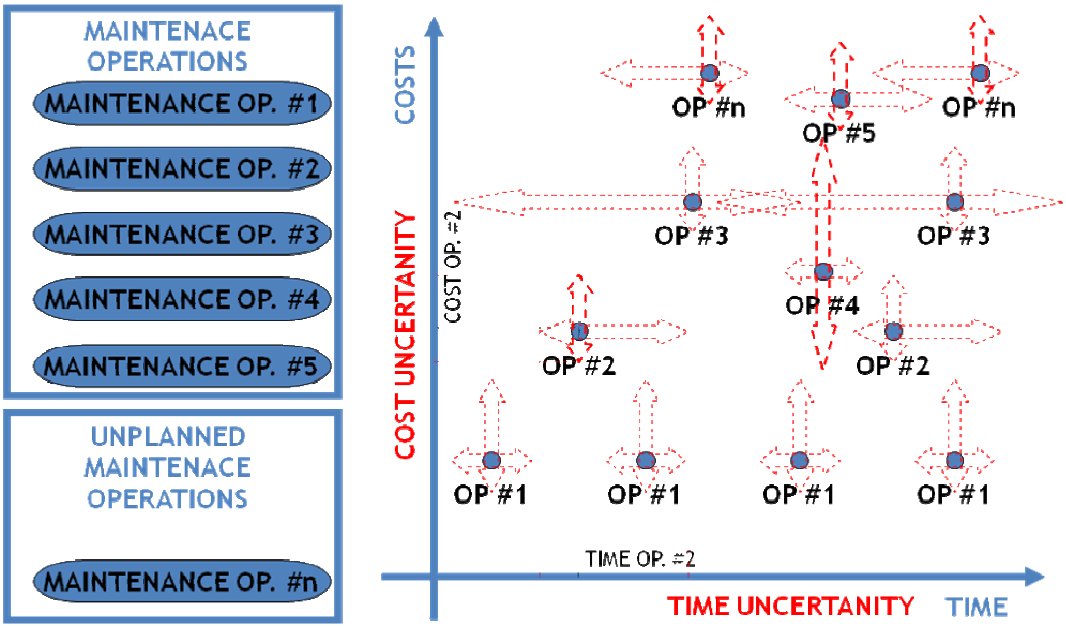

Fig. 7 - Time and costs uncertainty in maintenance planning

5.- The proposed tool for building materials and components data collection

Through the analysis of Service Life management systems from the point of view of the necessary information to allow designers evaluating duration and planning maintenance, CSTB and Politecnico di Milano are structuring an international RSL database [6]; such a database will contain the input data necessary for service life management. This RSL database has been developed to collect a series of grids in which set of RSL are stored and indexed [7].

The set of RSL consists of:

- the duration in years, choosing among different type of RSL distributions, as shown in fig. 8;
- the failure mode;
- the selection of the several levels of factors in the grid;
- the complementary information such as year, place, sources, data quality, observations.

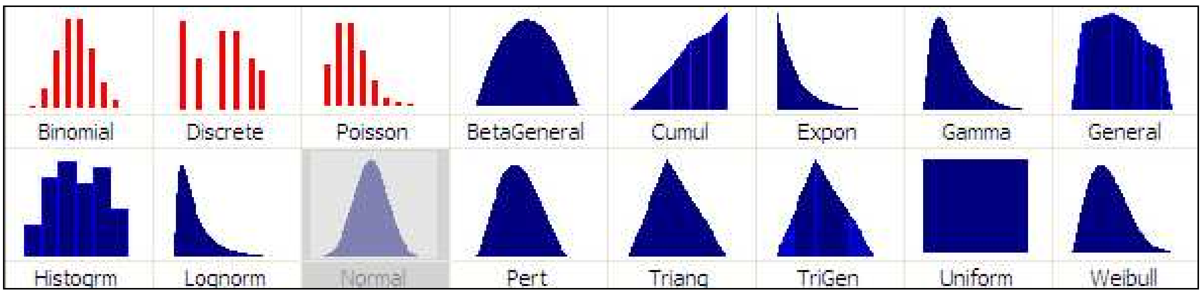

Fig. 8 - Different type of possible RSL distributions in the “SLP platform” database

During the documented Service Life capitalization for each grid, users can integrate RSL data according to the collected information. This information can have different origins:

- experience;
- ageing tests in natural environment;
- accelerated ageing tests;

- numerical simulation;
- bibliographical studies.

Another important peculiarity of this database is the possibility to be implemented by anyone, after the validation by the database administrator.

After the login, it is, in fact, possible to choose:

- to create or to modify a grid;
- to add new data;
- to consult already existing data.

The insertion of new data or the modification of already uploaded data is driven by a wizard in order to make such a tool as user-friendly as possible.

The SLP platform will not only contain a collection of data, but it will be also a service life prediction tool: it will be, in fact, implemented on one hand by evaluating grids [8][9] and on the other hand by the so called Evolved Factor method, in calculating Estimated Service Life. Durability of Building Components Group has been developing some criteria in order to make factor method as more objective and scientifically validated as possible: through a probabilistic approach, the proposed method uses the same equation proposed by ISO 15686-2 [10], but treating factors as aleatory variables and adopting Monte Carlo method for solving the equation. Aleatory variables' use describes better the complexity of decay and provides both the Service Life and an esteem of data's reliability: it is possible to obtain an evaluation of duration with precise probabilistic guarantees.

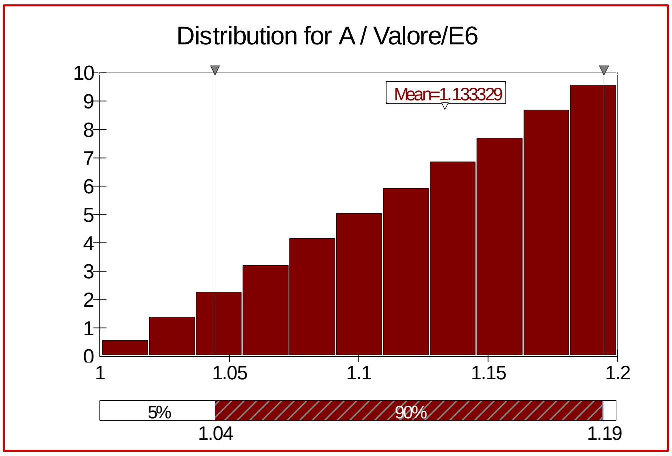

Fig. 9 - Enhanced Factor method: probabilistic (triangular) input for factors [5]

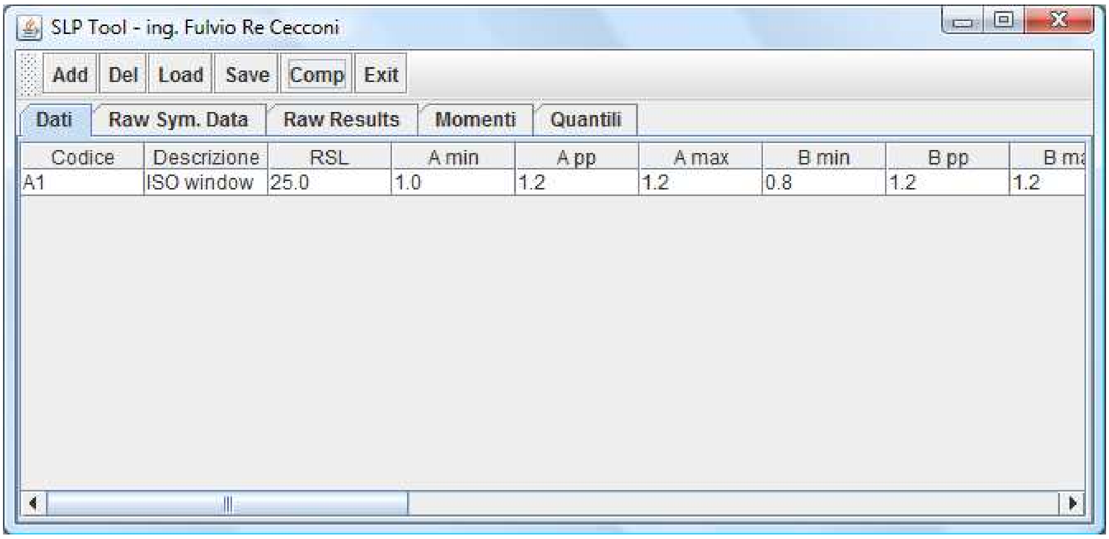

Fig. 10 - Software SLP Tool to apply Enhanced Factor method [5]

6.- Concluding Remarks

It has been shown that the type and accuracy of data which are needed when planning the service life of a building component depends on the stage of the design process when the planning is done and on the method used to estimate the service life of the component. Of course different methods will also give different reliability of the obtained results.
These consideration have guided Politecnico di Milano to propose a tool for building materials and components data collection and service life prediction that can be used in different stage of the design process because it provides different type of data with different accuracy and is able to measure this accuracy in order to give, when necessary, reliability information.

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