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BACK TO 4.0:

RETHINKING
THE DIGITAL CONSTRUCTION INDUSTRY

A cura di

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INDICE

"Application of the of the *depreciation cost approach* in the choice of the maintenance strategies"

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Topic: *Life Cycle Management*

Abstract

Often, the choice of the best maintenance strategies for the management of the housing capital takes as a basis situations or contingent choices, with the consequence of making a prevalent use of corrective maintenance, or of overlooking more appropriate estimative approaches.
The work proposes the application of the method of the depreciated reconstruction cost (or depreciation cost approach) to the complex problem of the individuation of the most appropriate criteria for the management of the service life of a building component. Usually, in fact, there are various possibilities, which involve consequence that differ between them on an economic, technological and fruitional point of view:

- absence of interventions, in order to produce the 'consumption' of the performance of the component during its service life;
- regular activity of maintenance, which always allows performances to be close to their initial value, with little but constant shares of expense as a consequence;
- programmed interventions of maintenance of major entity in presence of significant decreases of the level of performance, in order to lengthen the service life of the component.

The choice of the most appropriate strategy is often determined by issues tied to the opportunity of the moment, considering the available budget or the convenience in its immediate execution in opposition to the possibility to differ the moment of the intervention of maintenance.
The aim of the present work is to offer a more reliable to individuate, for each component, which one is the most opportune strategy, considering the depreciation it is subjected to during time as a consequence of its performance decay, which is tied – as it is suggested by the methodology of the depreciated reconstruction cost – to physical wear and tear, income decay and functional obsolescence.

1. Introduction

Each building component is subject, in its life cycle, to a decrease of performance, with characteristics in terms of law of variation that depend on a complex series of factors, making predictions quite problematic.
Actually, the possibility to predict the exact time of the failure of a component is first tied to the absence of pathological causes: in the diagnostic methodology, in fact, it is necessary to ascertain if the damaging event is linked to physiological factors, and hence if the solution of the problem is only linked to the removal of the effects and not also to the removal of the causes (Nicolella, 2003).

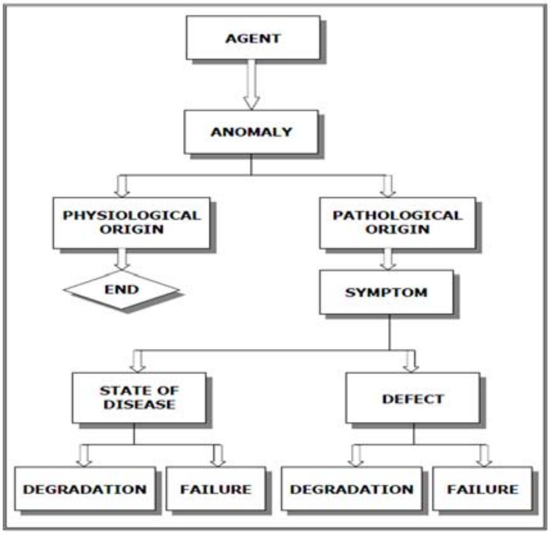

Fig. 1 – Procedural methodology for the diagnosis

In any case, building components – more than those, for example, in the industrial field – are characterized by a number of situations that significantly complicate the possibility to express prediction on the dynamics of failures:

- the non-bistability, because of which there is a range of intermediate performances between the initial testing one and the lowest one in the end of the life cycle, and it is not easy to associate to them an evaluation on the best opportunity to perform interventions and on the typology of works;
- the complexity of measurement of performances, which characterizes most components in use, excluding the structural components and some others;
- the necessity – in reference to the previous point – to find the performance that is associated to the state of failure (that is to say to the end of the life cycle), as it is rarely possible to have a measurable value, and it is necessary to make use of descriptive codifications (Nicolella, 2000).

International codes, as well, refer to this modality: ISO 15686-7, for example, considers 5 performance degrees, as it is represented in the table reported below.

Performance degree 0	No symptoms
Performance degree 1	Slight symptoms
Performance degree 2	Medium
Performance degree 3	Strong symptoms
Performance degree 4	Totally unacceptable, including collapse and malfunction

Table 1 – Performance degrees in ISO 15686-7

2. Maintenance strategies

To each performance degree that occurs at a certain time, a certain type of intervention is linked (Table 2), aimed to the recovery of performance of an entity related to the typology of works that is programmed. (Nicolella, 2003).

MONITORING/INSPECTION Intervention aimed both to a control of congruency between the plan predictions and the effective behavior in service, and to the maintenance strategy under condition: in both cases, it is aimed to the individuation of abnormalities that give start to imminent issues of safety, hygiene and fruition in general.
CLEANING/SUPERFICIAL INTERVENTION Intervention of superficial typology, either because it is carried out on finishing components, or because it involves the most superficial layers of components that are not superficial themselves: these are not invasive interventions, with very low or no technological involvement of other parts.
REPARATION Intervention focused on the clearance of abnormalities, in the aim of the recovery of the initial conditions, even when the performances realized don’t result to be corresponding to those (but higher than the fixed minimal degree in any case), to be executed to lengthen the mean life of the part until the intervention of total substitution.
SUBSTITUTION/INTEGRATION Intervention where a part of the element, of the sub-system or of the system, is removed because superficial interventions and reparations are not sufficient or not possible, that is to say in which the removal of the abnormality and/or of the deficiency results ineffective in absence of addition of new parts, or of a general modification.
TOTAL SUBSTITUTION It coincides with the ‘death’ of the element, and so it identifies its life cycle: its total substitution gives start to a new program that will consider its mean service life again.

Table 2 – Classes of maintenance interventions

It is evident that the cycle represented in figure 2 needs an ‘input point’, meaning that it is necessary to determine which one is the element having priority, to which the others correspond consequently.

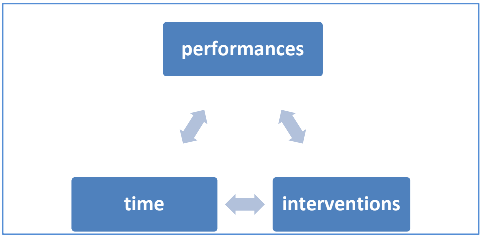

Fig. 2 – Biunivocal bonds between time, performance and interventions

It is considered absolutely necessary that the choice of the maintenance strategy comes from a preliminary evaluation of the typology of works (as explained in Table 2) that are supposed to be executed, as it is possible to manage the obsolescence of a component in different scenarios.

One possibility is certainly represented by the absence of interventions, and in this case the initial performance is naturally 'depleted' during the life cycle of the component: the ISO 15686 code defines that time threshold the 'natural duration' (graph in Figure 3.1).

The second scenario, which considers a politics of maintenance interventions of intermediate degree, executed in correspondence of performances that usually foreshadow a significant increase of the probability of failure of a component: this strategy, compared to the first one, allows a lengthening of service life (graph in Figure 3.2).

There is finally a third possibility, represented by the execution of interventions of minor entity, aimed to the removal of the decreases of performance, executed as a perceivable sign of decay appears: this strategy, for some components, implies a significant increase of the service life (graph in Figure 3.3).

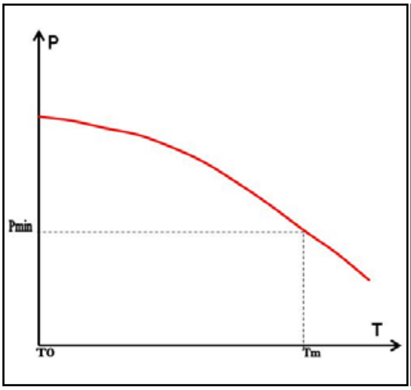

Fig. 3.1

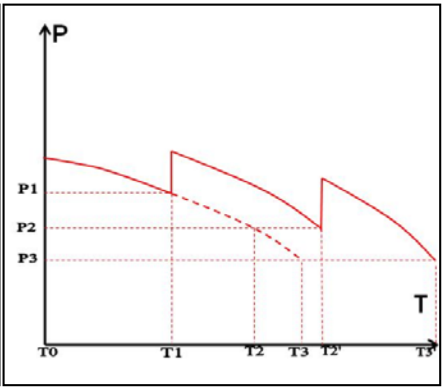

Fig. 3.2

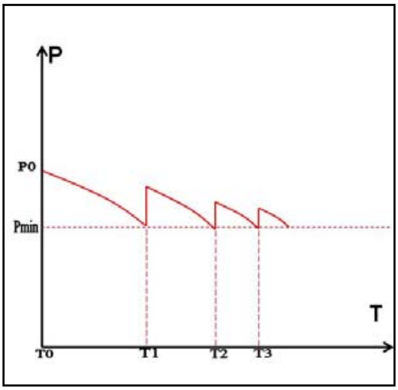

Fig. 3.3

The choice of the most appropriate strategy cannot overlook the evaluation of a number of circumstances and factors, such as:
- the possibility to delay the intervention, linked to the approaching of states of danger or, more in general, of out-of-service states;
- the consequences that a failure can determine for the estate and for things and people, also of a third party.

The problem, actually, is mainly economic, as it is necessary to take into account:
- the total cost to sustain in a given time threshold;
- the consequential issues to the execution of interventions: the indirect costs, related to the interventions that need to be executed on the other components connected to the object of the program, the necessity to stop – in part or completely – the income of the element;
- the budget of expense in the availability of the client.

A hypothesis of particular interest in the aim of the evaluation of the most opportune time and typology of intervention can be represented by the application of the depreciation cost approach as, through its use, it is possible to monetize the decrease of performance of a component during its life cycle and, consequently, comparing this value with the cost of the maintenance intervention, to allow a correct comparison between the different scenarios described above.

3. The depreciation cost approach

The depreciation cost approach follows the principles of *International Valuation Standards (Cost Approach)* and it is based on the postulate of substitution of evaluated assets. This economic principle affirms that, considered the nature of the factors of production of the evaluated components, if the market shows no direct appreciation for them, their possible value does not exceed the amount corresponding to the sum of the value of the area and the cost of reproduction of components that are comparable with the evaluated assets for the complex of the related relevant characteristics (including the current in-use condition, Del Giudice, 2015).

Using the “depreciated reconstruction cost”, the market value of a building must be determined as a sum of the following components:
- substitute value or reconstruction cost (surrogate value), with current market prices, of existing building products, technological systems and special works, excluding the deductions for physical wear and tear and obsolescence, if present;
- market value of the area where the building products are located (including the attached areas).

The basis for the employment of this procedure is the acknowledgement that buildings tend to decrease their market value over time. According to the estimative logic, this value reduction is to be reconnected to three factors: physical wear and tear, income decay and functional and economic obsolescence (Manganelli, 2001).

The first two factors, though economically different, are both an expression of physical depreciation. Physical wear and tear origins from the limited economic life or service life of the building and from the decrease of its efficiency. Income decay reflects the reduction of utility of a building in use, compared to its corresponding condition if it were new, as the passing of time requires more numerous and more expensive maintenance interventions in order to keep the same conditions of efficiency. Analytically, physical wear and tear is considered equal to physical depreciation, while income decay only includes the decrease of value related to the absence of programmed maintenance, that is to say to the missed execution of interventions of ordinary maintenance, making interventions of extraordinary maintenance necessary (the latter are calculated proportionally to the expenses that were not paid for ordinary maintenance).

The third factor can be divided into functional obsolescence and economic obsolescence: the former is a loss of value that can be attributed to the innovations of more modern technological systems, which have lower service costs and/or higher efficiency with the same cost of construction; the latter is a loss of value related to the conditions of the environment and the surrounding properties, in addition to particular events that can reduce the value of the asset. The depreciation for economic obsolescence, then, can occur because of a variation of the “external conditions” of the evaluated asset, such as possible changes in the destination of use of the inhabited areas, pollution and urban congestions, general economic situation, etc. Often, these factors can in fact determine a significant reduction in the income of the human and productive activities carried out in the building.

The depreciation can be also distinguished in *curable* and *incurable*, respectively whether the cost of a possible restoration or requalification aimed to recover the loss of value is lower or higher than the loss of value that would be recover: in the former case it is curable, while in the latter the intervention of maintenance would be inconvenient, and so the depreciation is incurable (this usually happens when economic obsolescence is prevalent).

3.1 Estimation phases

As the constitutive elements of a building are notoriously heterogeneous between them, in function, time of realization, technological characters and typology, in

complex cases, when a higher degree of deepening of the evaluation is required, the depreciated reconstruction cost has to be determined by functional elements, according to the following operational phases (Del Giudice, 2014):
- individuation of the building typology and classification, when possible, of the products, the assets or the components in homogeneous groups;
- evaluation of the reconstruction cost of the building products, assets or components as above;
- breakdown of the building in functional elements and calculation of the percentage cost of the single elements on the total cost;
- definition of an analytical depreciation function for each functional element;
- evaluation of the depreciated reconstruction cost for each functional element, with the following aggregation of the various items, in order to obtain the total value of the depreciated reconstruction cost of the building.

3.2. Depreciation functions of the functional elements

After dividing the building products into the respective constitutive elements, and evaluating the reconstruction cost and the percentage of incidence on the total reconstruction cost of the building for each of them, it is necessary to define an appropriate depreciation function for each of the functional elements mentioned above.
Each depreciation function is defined as the sum of the quotas corresponding to the different depreciation factors that influence the state of the specific element considered. Then, to each depreciation factor corresponds a partial contribute to the total depreciation of the asset considered (partial depreciation).
The quotas of depreciation are also defined in relation to the mean economic life of the functional element considered, to the cost to pay for the interventions of extraordinary maintenance of the element, to the ordinary period between two interventions of maintenance. These parameters can be obtained from the information in the main bibliographical references (Molinari, 2003; Manganelli, 2011 and 2013).
In particular, the depreciation factors with influence on the evaluation of the depreciated reconstruction cost synthetically go back to:
- physical wear and tear;
- income decay.
Another value reduction, due to functional obsolescence, should be considered for the systems. Yet such an evaluation, which is quite complex, would cause significant operational problems, concerning the determination of some essentials parameters such as the expenses to dismantle existing systems and/or the installation of new systems, and the lower expense or the higher utility generated as a consequence of the substitution of the system. Because of these reasons, often the existing literature suggests to avoid the analytical calculation of the depreciation caused by functional obsolescence, considering its influence in the depreciation caused by physical wear and tear, specifically taking it into account empirically by adopting, for systems, an economic life that is lower than service life and/or by varying the discount rate (Manganelli and Morano, 1997).

That said, the formal relation that literature suggests to quantify the contribution of the depreciation factor identified with the physical wear and tear is the following (Morano N. et Al., 2009):

$$\Delta C_{dlog} = (C_0 - Vr) \cdot \frac{(1+i)^n - 1}{(1+i)^v - 1}$$

where:

ΔC_{dlog}	depreciation by physical wear and tear;
C_0	initial value of the functional element;
V_r	residual value at the end of the service life of the functional element;
i	discount rate;
v	number of service life years of the functional element;
n	the number of life years spent by the functional element at the moment of the evaluation.

Estimative theory affirms that the partial contribute of the income decay to depreciation has to be related – as long as it is a *curable* depreciation – to the cost of the necessary additions to eliminate it, decreased by the residual value of the part/component/element that was substituted. Assuming the substituted part has no residual value, and then the cost of the additions can be determined as the financial sum of the annual quotas of reintegration accumulated in order to reach the expense for the intervention of extraordinary maintenance at the expected moment of execution.

Then, the deduction by income decay, equal to the one the building would receive in absence of interventions of maintenance can be analytically determined with the following formula (Morano N. et Al., 2009):

$$\Delta C_{dred} = C_0 \cdot m \cdot \frac{(1+i)^n - 1}{(1+i)^s - 1}$$

where:

ΔC_{dred}	depreciation by income decay;
C_0	initial value of the functional element;
m	cost of the intervention of extraordinary maintenance, expressed as a quota of the initial value of the element C_0;
i	discount rate;
s	standard period between two intervention of maintenance;
n	the number of life years spent by the functional element at the moment of the evaluation.

Then, the related depreciation coefficient is calculated for each functional element basing on the analysis carried out, and summing the corresponding partial contributes of physical wear and tear and income decay, which has influence on the total reduction of the reconstruction cost of the element. For the functional elements considered, the discount rate to employ in the depreciation functions for physical wear and tear and income decay can be evaluated equal to the legal interest rate, in order to

consider the worst situation. In fact, this rate of extremely small entity generates the worst conditions of depreciation on the analytical aspect.
The parameters at the basis of the calculation are synthesized in the following Table 3. In the table the information on service life of the functional components are reported in columns “c” (with interventions of maintenance) and “a” (without interventions of maintenance); the information on the optimal period and the cost of maintenance for each functional element considered are then reported, respectively, in columns “b” and “d” (Morano N. et Al., 2009).

Functional element	***Years***			***%***
	a	***b***	***c***	***d***
Masonry structures	*83*	*15*	*300*	*11*
Reinforced concrete structures	*65*	*40*	*120*	*30*
Wood structures	*65*	*40*	*120*	*30*
Insulation and waterproofing	*30*	*4*	*90*	*8*
False ceilings	*40*	*15*	*75*	*18*
Paving	*60*	*20*	*85*	*10*
Paint	*5*	*-*	*5*	*100*
Window and door frames and steel works	*50*	*15*	*80*	*10*
Electrical and special systems	*35*	*-*	*35**	*100*
Elevators	*35*	*5*	*60**	*5*
Water and sanitary and fire system	*33*	*10*	*40*	*5*
Air conditioning system	*15*	*-*	*15**	*100*
Outdoor installations	*35*	*20*	*60*	*25*

Table 3 – Service life, optimal maintenance periodicity and maintenance cost of functional elements

Where:
a is the service life of the functional element in absence of interventions of maintenance;
b is the period considered as optimal between two interventions of maintenance;
c is the service life of the functional element in presence of interventions of maintenance;
d is the cost of an intervention of maintenance, expressed as a percentage of the initial value of the functional element.
The asterisk in some squares of the table indicates that economic life is being considered instead of service life there.
On the basis of the parameters reported in the table, the depreciation at the time of the evaluation for each functional element is calculated, considering the moment of the execution of the functional element or the main component of the building product (in case of functional elements that are accessory or complementary to the main component) as the initial time. Eventually, the total depreciation is obtained with the following formal relation:

$$D = \sum_{i=1}^{n} d_i$$

Where:
D total depreciation of the building asset;
d_i depreciation related to the *i-th* functional element of the building asset.

4. Conclusions

The presented work constitutes a necessary premise to the application of the depreciation cost approach to the economic evaluation of the performance decay of the building components: the comparison between the results obtained in recent years in the field of durability, and the potential of this methodology, shows the possibility to build economic value/time curves along with performance/time curves. Those will make it possible to build recovery cost/time curves, which will provide the possibility to know less discretely the variation over time of the increase of the cost of the intervention of maintenance, and then individuate the most opportune moment to intervene. Of course, the issue of the technological and operational connections that exist between the different components (Nicolella, 2003) has to be cleared out, making the problem even more complex.
At the moment, the focus of this research is the construction of the first step, that is to say the construction of recovery cost/time curves for some of the main building components, such as elements in reinforced concrete, external covering in painted plaster, waterproofing of plan roofing.

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