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Maintenance of buildings: Italian examples of deviations between planned and incurred costs

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Abstract. In recent years, drawing up the maintenance plan for a building has proved to be a theoretical practice, which has been expressed in the indication of a multiplicity of interventions more for caution reasons than for real needs. In this way, the document (mandatory by the Italian law both for public and private works) has been interpreted as a formal requirement: it must be part of the project, without any particular operational interest. So, the maintenance plans are more often "standard plans", not directing the user towards a specific maintenance strategy and thus consolidating the common thesis that reality is different. The paper compares, with reference to two xxx of study (offices and residence), the planned maintenance actions and those carried out, with an indication of the difference between expected and incurred costs.

1. Introduction

The Maintenance is defined as a complex of activities necessary to preserve the performance of technological and structural elements over time [1], with the aim of conserving the building assets (and also equipment) for the entire service life, that period of time between the service kick-off and the moment when the repair is uneconomic.
The Italian reference legislation (the new Code of Contracts, the Construction Act, UNI standards) clearly distinguishes between ordinary and extraordinary maintenance (Table 1).
While the New Code on Public Contracts and Buildings Consolidated Law indications are mandatory, the technical standards issued by UNI (Italian National Unification Body) are representative of a voluntary level and therefore may not be applied.

Table 1. Summary of national definitions.

	Ordinary Maintenance	*Extraordinary Maintenance*
New Code on Contracts [2]	*Repair, renovation and replacement works necessary to eliminate the deterioration of the structures, in order to preserve the condition and the usability of all the components, systems and*	*Works and modifications necessary to renew and replace structural and other parts of the buildings and the relative appliances, to adapt the components, systems and works connected with their use and the regulations in force and with the*

	connected works, keeping them in good working order and in safe conditions	*aim of reducing the significant deterioration*
Buildings Consolidated Law [3]	*Building works relating to the repair, renovation and replacement of building finishes and those necessary to integrate or maintain existing technological installations*	*Works and modifications necessary to renovate and replace structural and other parts of buildings, as well as to implement and integrate sanitary and technological facilities, provided that they do not alter the overall volume of buildings and do not entail any change in their intended use*
UNI Technical Standards [4,5]	*Minor repairs, requiring only small parts, which involves the use of consumables of normal use or the replacement of small parts*	*Particularly important activities or special equipment or instrumentation, which involves repairs and/or replacement parts, provides for the overhaul of structural elements*

Theoretical parallels between maintenance in construction and industry are frequent although in the first case we talk mainly of degradation and obsolescence, while in the second case of failure and the industrial outcome can usually lay on a robust reliability database concerning the behavior of serial products, while a building behaves as a prototype mainly.

During the life cycle of a building, maintenance is responsible for bringing the system's performance back to values that allow its use, despite the ageing of the asset; in other words, maintenance actions aim to compensate the "natural" decrease in the asset value and initial performance. As is well known, a building system is gradually declining and loses part of its functionality: this phenomenon is defined as obsolescence and can be limited but not eliminated, since, as in the case of building materials, it concerns its natural aging and loss of performance [6, 7].

From the theoretical point of view obsolescence can be normative, physical, technological, functional and formal. The most frequent causes may be mismanagement or inappropriate use; accidental phenomena or environmental effects; design or construction errors; the appearance of defects or abnormal behavior [7, 8].

Maintenance is related to different phases of the construction process: at first, to the design phase, when it is necessary to foresee it in technical and cost terms; to the construction ones, to check that it is carried out correctly; during the asset management, through minimum or more substantial interventions; at precise control times, when it is possible to think about possible intervention strategies.

Other definitions of maintenance [9, 10] refer to the intervention strategy: scheduled maintenance is, together with condition maintenance, a type of preventive maintenance; instead, corrective (or fault) maintenance is a type of maintenance that provides for operations to be carried out only after failure has been detected; the latter is a strategy that can be adopted where there are non-critical and easily substitutable systems at low cost: it is therefore more convenient to wait for the maintenance to be carried out.

These two approaches essentially distinguish the theoretical case (planned maintenance) from the real one (corrective maintenance): the paper will reveal, in both case studies, substantial cost differences, which will be useful in improving preventive estimates. The calculation of total costs in the theoretical hypothesis (indications of maintenance plans) will be limited only to those interventions with a high probability of being carried out, for example skimming a large part of preventive inspections. We expect different values, significantly lower than the theoretical ones; then we will compared them with the annual incurred costs, after a short and limited period of management.

2. Maintenance plan: structure and contents

The P D no. 207/2010, now overtaken with many critical issues by the New Code of Contracts [11, 12], defined the maintenance plan as a complementary document to the executive project, which includes graphical drawings and provides for the maintenance of the intervention with the aim of maintaining its functionality, efficiency and quality characteristics over time.

It consists of a set of documents (User's Manual, Maintenance Manual and Maintenance Program) which are intended to provide useful information for the correct use of the asset, its correct maintenance and management. The User Manual is the document that encloses the operating instructions in non-specialist language and is intended for users; the Maintenance Manual is intended for technical personnel who will arrange the maintenance or management of the property, therefore it will be written with a technical - specialist language. Finally, the maintenance programme, which is more operational, is divided into three sub-programme: of services, of controls and of operations.

The main weakness comes out from the scheduled step to provide all the maintenance documents. Before the bidding and the end of construction phase it's impossible to determine the manufacturer and the model of components provided by the contractor (during the construction step) and so part of the maintenance planning is necessarily generic (and thus is why the maintenance plan is considered as another bureaucratic requirement not linked to any useful operational issues).

The most commonly used UNI maintenance standards are UNI- EN 10604:1997 " Maintenance - Criteria For Design, Management And Control Of The Maintenance Services Of Building ", aimed at providing general management criteria and tools for the maintenance of real estate assets, and UNI 11257:2007 "Maintenance of real estate assets - criteria for drawing up the plan and maintenance programme of real estate - Guidelines", which details the criteria through which plans can be drawn up.

In operational terms, if there were buildings thematic archives showing the frequency of failures and pathologies, writing these documents would be easier, less repetitive and more accurate, and it would have more scientific validity than today. The most rigorous professionals refer to foreign databases, which nevertheless show critical issues linked to the reference compass and the construction technologies they represent.

3. Estimated maintenance costs for case studies

The analysis in this paper will demonstrate the necessity to overcome the "simplified methodology" provided by Italian law to plan the building maintenance, because of its unreliable connection with the real maintenance costs, both in residential and office buildings. To give evidence to these facts, we'll consider two examples, one residential and one office building. In both cases, these are new constructions with reinforced concrete load-bearing structure and vertical closing elements in brick, external plaster finish.

Table 2. Case studies: key figures summary.

	Residential Buildings	*Office Buildings*
Construction costs	*6,4Million Euros*	*3,77 Million Euros*
Year of construction	*2012*	*2016*
Area	*4.350 sq. m.*	*2.500 sq. m.*

In both cases, the maintenance programme is available, with an indication of the planned project of controls and interventions: as far as the residence is concerned, since it has been in operation for more than 5 years, the final accounts of the costs incurred for ordinary maintenance are also available.

The analysis approach aims to determine any deviations between theoretical and operational costs, derived from the final balance sheet. In particular, the research has been developed:

(1) by calculating the cost of checks and operations theoretically provided by the designers,

(2) by comparing it with the theoretical cost used for the preventive estimates;
(3) by identifying controls and operations that are most likely to be carried out (and their related costs)
(4) and by verifying the costs really incurred.

At first we defined inspections and intervention costs (provided by inspection and operation programme) through a quantity survey, where a typical workers team and an average time for each operation were estimated and these values were associated with the hourly labor costs (referred to the second half of 2016), with particular reference to the case studies geographical area (Piedmont Region) [13]. The overall value, appears to be largely overestimated, because the controls provide for visual investigation of all the technological elements that can be inspected and the interventions for the restoration of all these elements, in the event of failure or pathology that compromises their correct use. The first comparison wants to relate these theoretical design activities/costs (which are defined in the executive design phase) and the synthetic forecast ones, typical of the programming phase. The value, so far from the initial forecasts, depends on maintenance plan contents, often related to future actions and containing even more than the actions normally due...

We simply considered the control activities propensity (in Italy, it is not usually done in a preventive way, but in a "corrective"); therefore, we choose to consider only controls over those technological elements with a higher probability of failure was considered.

In order to determine this probability of occurrence, some foreign databases were consulted and the information was verified through market surveys of Italian operators in the construction sector. Then we decided to estimate the costs of inspections for which the occurrence rate was more than 25% in order to increase the reliability of this survey methodology. As far as the interventions are concerned, on the other hand, and in the same frame the costs of the interventions have been calculated, at which the probability of occurrence is greater than 30%. At the end, the actual costs are those derived from the items of expenditure actually incurred by the owners. Table 3 shows briefly the results.

Table 3. Summary of research results.

	Ordinary Maintenance (annual costs)	
	Residential Buildings	*Office Buildings*
Planned costs (from design phase)	*0,43% of construction costs*	*0,57% of construction costs*
Planned costs (from programming phase)	*0,30% of construction costs*	*0,30% of construction costs*
Planned costs (by occurrence analysis)	*0,18% of construction costs*	*0,18% of construction costs*
Real costs	*0,15% of construction costs*	*0,16% of construction costs*

4. Conclusions and future research developments

The processed data are certainly interesting, because they show how often people tend to overestimate these costs in the forecasting phase or prescribe behavior far from what happens in reality. However, some clarification is needed. The data collected can be used for the intended use indicated and for buildings of the same age and destination/technology. So these parameters cannot be used extensively on all existing assets. For this reason, it is necessary to deepen the theme by extending the data

collection to other destinations of its more typically public (sporting, social, health,...) or private (commercial, industrial,...) and to cases of intervention on existing heritage. From a theoretical point of view, for some categories of components, generations of older buildings (1995-2004) have fewer defects than younger generations (2010-2012), even if the latter do not yet have a significant burden of disease on the whole guaranteed life of the building; this observation can generally be extended to all comparisons between generations of constructions. The analysis of the databases, even if not directly referable to the Italian building heritage, therefore also with different construction techniques, provides interesting data but does not yet allow to obtain a frequency of defects on the various building components. In conclusion, the two investigated case studies show the provisional simplified design methodology for maintenance planning is very far from the real maintenance costs. For this reason, even it is admitted by Italian law, it should be avoided and substituted with a reliable and wide spread database of real life maintenance service for buildings.

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