DETERMINATION OF CRITERIA FOR THE EXPLORATION AND FOR OBTAINING INDICATORS IN EVOLUTIONAL ANALYSIS OF DEGRADATION IN URBAN FACADES

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ABSTRACT

The interest of this research is motivated by the huge constructive development in the building sector, which has led to an enormous volume of buildings worldwide over the last decades. This fact, as well as poor management in conservation of buildings, mainly in urban cities, has led to total degradation situations on the facades of building stocks. To infer on the evolutional process of degradation that occurs in the facade, during its service life and based on the information obtained from inspections, the method for the data analysis (e.g. survival analysis techniques) is as important as the truthfulness and usefulness of the data collected on the subjects (facades) under study.

In this paper we propose a method based on the design of indicators for prospecting and global data collection on the injury state of the inspected facades. The method analyzes how to perform the identification, classification, methodology, resources and quality of the data in order to be reliable, testable and measurable. The proposed model enables the macro inspection and monitoring of large-scale urban zones and the data obtained allow the researcher to understand and manage the predictive degradation phenomenon and, in turn, eliminate potential risks in the urban front.

Keywords: Criteria validation, Data collection, Durability indicators, Inspection methodology, Risk analysis, Service life estimation.

1 INTRODUCTION AND STATE OF THE ART

In relation to the acceleration of the process of urbanisation and construction in recent decades in most big cities, the debate on the conservation and maintenance of the built environment is open. In addition, questions about how to articulate conservation measures in the construction sector are discussed. This is an important issue because the measures affect significant sustainable positioning for the future of the cities and their metropolitan areas. This research focused on the real evolution of the degradation of the facades of residential buildings, within their service life, regarded as a part of the fronts of the urban space of the cities, in which lies a great burden of media and social coverage.

Surely all decisions of intervention need, as a preliminary condition, of having as much good information as possible, therefore we need to determine what criteria and what indicators are needed to establish the evolutionary analysis of the degradation of urban facades. This paper shows a massive inspection methodology, with the aim of finding the optimal information to facilitate future statistical studies of durability and survival for each one of the construction processes of the urban front.

As a result, and despite the existence of some important experiences at different scales in the building sector [1], the methodology we are going to develop here is unique because it pursues the analysis of samples of study much larger and that force you to the application of multi-scale techniques. The methodology of inspection that pose to display a model designed for the control of the durability of urban facades, depending on the risk of an injury that these represent. It is scheduled for a data collection setting, wide, generalist, robust, and aimed at the whole population, and it makes easier the use of specific algorithms. This will give us a better understanding of what happens to the facades throughout its service life. Through this method it will be possible to propose preventive actions for the future within a territorial approach on a large scale.

The proposal raises field datasheets that collect all those parameters that contain relevant indicators for each of the subdivisions, in which each facade has been divided. However the interest focuses, on one hand, on the degree of accuracy of the resulting information coming from the data and, on the other hand, on the reliability of the methodology of inspection regarding the state of degradation of the facade elements.

Therefore one of the concerns of the proposal consisted in observing patterns of urban growth, as well as those that define the city considered as a part of a comprehensive system with certain hierarchies that mark the interconnections between them [2]. The description of the study scale in order to analyze different magnitudes of samples, has been defined by various researchers as the microscale, mesoscale and macroscale [1, 3 and 4]. On the basis of this classification, the concept of multiscale studies arises -in order to provide a better understanding by the up-and-down flow of the information available between different scales. An example of a multiscale study is conducted by Gluch *et al.* (2006) [3], in which a thermic analysis is created in order to better understanding the urban microclimate. Other authors apply their representations of the atmospheric environment in urban areas by reducing the regional scale to a city scale, using computational models [4]. The effects from mesoscale to microscale and vice versa were discussed by the authors and they concluded that, in a general sense, the scalar interaction can play an important role in all directions.

In our opinion, all method aimed at permitting broad inspections, in this case the building facades, must be able to show a clear traceability towards the aimed resul, allowing the adjustment of the parameters through the use of decision making techniques, such as the comparative techniques of analytic hierarchies (AHP) [5], ELECTRA [6] or the axiomatic method by Raynaud and Arrow [7].

One of the studies in urban scales, even though they are rare among the scientific community, is made by Mendes da Silva *et al.* (2010) [8] for the old town buildings of Coimbra (Portugal). The project focuses on the concerns of the conservation of the existing heritage. It also shows how to develop a platform for management of the park, aimed to the achievment of the social and economic improvement of the area. To carry out the study, it was necessary to understand that the process of improvement could not be sustainable without a prior vulnerability and risk assessment of the state of the buildings. The data could be implemented using a multi-purpose tool, connected to a relational database within a Geographic Information System. The methodology that they apply is practical and flexible, and it allows a multidisciplinary management, in addition to the potential applicability to other areas, cities and buildings just introducing some slight adjustments of the parameters. Another study that focused on the durability of buildings on a urban scale, is the methodology of evaluation introduced by Rodrigues *et al.* (2011) [9], which is based on the premises that the mechanisms of deterioration are the consequences of the interaction of two independent variables: the building, such as a physical object, and the environment, as a source of agents of acceleration of the deterioration process. The methodology has allowed the development of tools to support the systematic study of visual defects in the bound of the buildings. The matrix designed by the authors for the visual observation extends the application of Failure Mode and Effect Analysis (FMEA) techniques for the qualitative analysis of risks, and it represents an important guideline for the design teams.

2 MODEL PROPOSAL

This section develops the methodology in order to perform the analysis of the whole building park at a macroscale level. The model defines the criteria to be taken into account when creating an inspection tool, through the creation of strategic indicators and their respective weights of importance, aiming to develop a standard inspection sheet. The structure of the proposed tool optimizes the information collected in the field, considering the elements of observation and his condition.

2.1 A network of urban laboraties approach

To define the boundary conditions under which this methodology has been designed to inspect heterogeneous samples of urban facades, we start from the conceptual and operational idea that the territory under study is subscribed inside the are delimited by the perimeter of the limits of the urban area of the city. This territorial space is what we call "urban laboratory" with the clear aim of being a centre of operations and strategies that allows us to link the experiences acquired with other urban laboratories, thus creating a collaborative knowledge framework for sharing predictive formulas of conservation and sustainable maintenance strategies of the urban front.

2.2 Durability goals

In the building sector there is no proven information to determine what is the evolution of the degradation of the facades over time, in terms of use and their exposure to external agents.

The proposed methodology allows the investigator to caracterize different type of injuries and categorised them according to their severity and magnitude levels, in relation to the risk that they represent for citizens in the public way. From this perspective, durability must be understood as the time to reach each one of these risky levels of deterioration.

Authors such as Serrat and Gibert (2011) [10] applied survival statistical models for estimating time to these levels of degradation during the service life of the facade. However, in order to achieve reliable results, it will be necessary to have a sample representative enough and repeated inspections throughout the life of the buildings.

Figure 1 shows the hypothesis that relates the causes of degradation of the elements of facade (C_i) with injuries arising in different levels (L_{ik}). It can be seen that different inspection times (I_j) get from the facade partial, but complementary, information on the evolution within a lesion and between lesions.

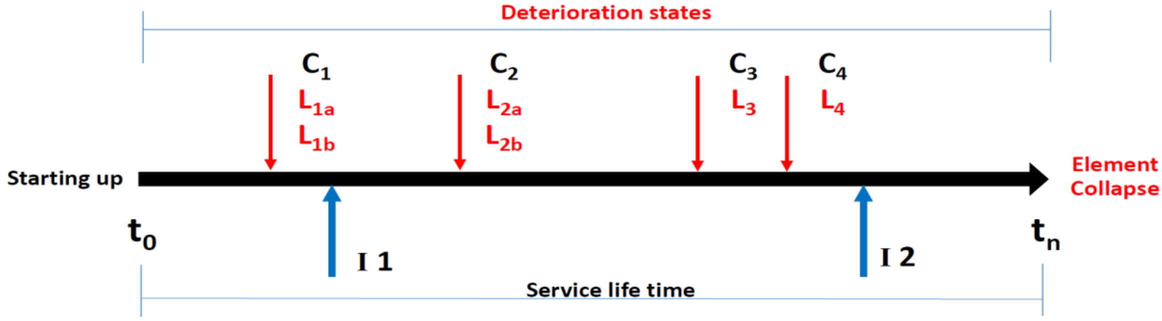

Figure 1: Illustration of the inspection methodoloy toghether with the progression among the different deterioration states along the service life of the façade.

Although the causes are responsible for the presence of different types of lesions that appear on the facades, our methodology will focus on collecting data based on the evidence of detectable injuries. This approach agrees with the goal of describing the most recurrent lesions at macroscale level, in order to know how they evolve over time and how they influence the overall durability of the facades.

2.3 Criteria proposal for the indicators

Most of the authors in this research field and those that they have reported experiences in the methodology of inspections at macroscale level, such as Jordana and Gibert (1999) [11], Peixoto de Freitas *et al.* (1999) [12], Mendes da Silva *et al.* (2010) [8] and Rodrigues *et al.* (2011) [10] support the idea of carrying out visual inspections as they offer greater representativity of the facts that investigators are interested in. However, for this it is necessary to fix the purpose pursued, the goals to be achieved, the types of data that are needed to compile and the methodology to be used. It is precisely in these strategic points, previous to the design, where maximum differences between authors are found. Although all agree the realization of visual inspections collected in a physical support of field datasheets, no consensual trend for data collection is given. In this regard, this circumstance may be due to the lack of common regulations among different countries.

After the analysis of the requeriments and the goals of the research study, the criteria that we propose to take into account in the inspection methodology, as well as the specific characteristics of each one of them, are shown in Table 1.

Table 1. Weighted criteria (in percentages) and indicators for the inspection methodology

General	Specific	Relative / Overall Weight (%)	General	Specific	Relative / Overall Weight (%)
Identification 17.5%	Descriptive	36.25 / 6.34	**Resources 11.25 %**	Technological	25.00 / 2.87
	Methodical	28.75 / 5.03		Human	35.00 / 4.03
	Universal	53.00 / 6.13		Time	40.00 / 4.60
Classification 16.25 %	Sequential	36.25 / 5.89	**Data 21.25 %**	Reliable	42.50 / 9.03
	Detailed	35.00 / 5.69		Quantifiable	31.25 / 6.64
	Ordered	28.75 / 4.67		Verifiable	26.25 / 5.58
Methodology 22.5 %	Robust	35.00 / 7.87	**Analytical skills 11.25 %**	Multifunctional	26.25 / 2.95
	Standard	30.00 / 6.75		Processable	41.25 / 4.64
	Quick	35.00 / 7.87		Longitudinal	32.50 / 3.66

2.4 Determination of the weights for the indicators

In order to determine the degrees of importance of each of the requirements, designed for the realisation of major inspections in urban facades, it was necessary to establish, by means of consulting experts, the weights based on a survey and a direct assignment strategy, in order to assess the degree of suitability of the inspection document based on the goals of the project.

First column in Table 1 shows the percentages of each of the requirements, among which we can point out that Methodology (22.50%) and Data (21.25%) are those that require greater attention. Looking at the third column we can see the relative (within the general criterium) and the overall impact of each indicator. As a consequence, all the efforts in the design of the inspection methodology must be focused on collecting reliable (9.03%) and quantifiable (6.64%) data, using a robust (7.87%), quick (7.87%) and standard (6.75%) methodology, and allowing a descriptive (6.34%) but universal (6.13%) identification of the facades.

2.5 Design of the areas to be inspected

The inspection of each facade includes the differentiation of three virtual vertical planes, where all those elements that form part of it are located. The first plane is the vertical closure of the building with the alignment in the road, the second plane represents the cantilever elements formed by balconies and, finally, the third plane contains all solid bodies of facades galleries. Once the planes of interest were established, we proceeded to determine what kind of information was necessary to collect either to eliminate the risk, or to enter into a process of adaptation and improvement of the facade. The planes mentioned above are shown in Figure 2. Next step will be to define on these planes the data collection on the basis of the constructive characteristics of each facade.

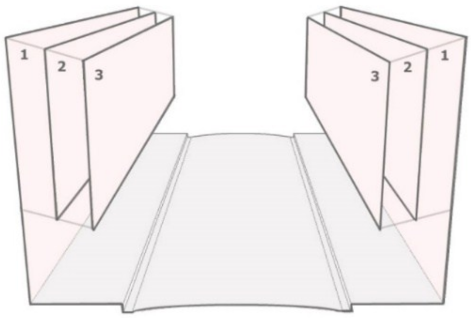

Figure 2: Representation of the virtual planes of the façade.

2.6 Data collection sheet structure

To preserve the essence of the predetermined requirements, it was necessary to establish a method of data collection that had to be fast without creating doubts in the inspector. It had to be standard and capable of bringing together the best information in the minimum possible space. The appropiate answer was given for a field datasheet. In order to achieve the expected results in the inspection phase, we designed general documents for a generic sample of buildings. The final documentation has been divided into two main blocks, one focused on the collection of information related to planning, building and uses, that allows to identificate the property, and another more specific for the information on the level of degradation of the elements on the facade under inspection.

Figures 3a and 3b contain the fields of those sections that are object of study in order to achieve the objectives and they allow, without loss of time, take the maximum information for future studies. This first tab collects data from different administrative databases and, after being compared with those on site, provides the homogenization of municipal information at the same time that allows to characterize the property for their age, type, usage, dependencies and the transformations that have undergone throughout of his life.

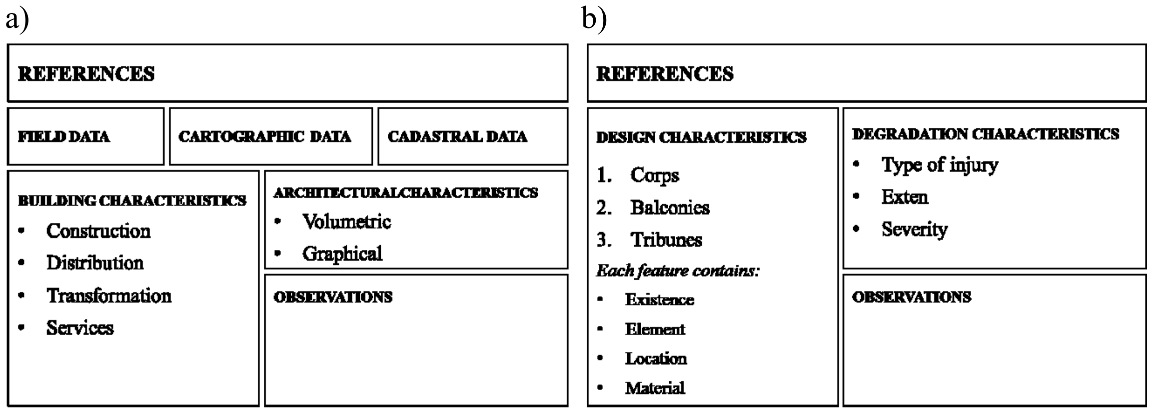

Figure 3: Field datasheet a) for the building and b) for the façade.

The scheme in Figure 3b shows two large sections where, systematically, we can collect (left-hand part) the different parts into which we have subdivided the facade, in concordance with the planes previously described, and (right-hand part) the type, exten and severity of the injuries.

Once we have fixed the sections, subsections and elements to be observed in the inspections, as well as the different concepts of classification of the status of each facade, we can design the field datasheets that will be used by different groups of inspectors for the collection of data.

The functional importance of the tabs and the apparent rigidity of its contents are essential to obtain information robust enough, aimed to determine the real status of the building stock. Despite this, it is necessary to instruct the inspectors to explain how they should organised the datasheets, what types of information they contain, as well as the criteria to be taken into account in front of a particular injury.

2.7 Application

The methodology introduced in the previous subsections, in preliminary versions, has been succesfully applied in several cities and locations. As a summary of the project and as a first picture of the results, Table 2 shows the location of the inspections, the number of inspected facades in each location and the percentage of facades in each severity level, in terms of the estimation of the time in which a maintenance action would be needed. Figures illustrate clear differences among locations and make evidence for the interest of a network of urban labs.

Table 2. Scope of the project for a network of urban laboratories

Country	City	Number of Inspected facades	Percentage of Actions		
			Long-term	Middle-term	Short-term
Spain	L'Hospitalet de Llobregat	13193	50	43	7
	Esporles (Mallorca)	291	43	51	6
	Barcelona (Ciutat Vella)	2631	24	53	23
	Barcelona (Eixample)	2736	39	49	12
Chile	Valparaíso	396	16	58	26
	Santiago de Chile	1403	28	61	11
Mexico	Mexico F.D.	525	16	21	63
Global state of the cities inspected		21175	42	47	11

3 CONCLUSIONS

In response to the problem of how to approach, at macroscale level, an analysis of urban facades, a standard inspection methodology for the collection of information on their conservation status has been developed.

The core of the inspection tool was created taking into consideration a number of key indicators that focus the interest in collecting data according to its importance. Its structure allows to differentiate the identification details of the building from the descriptive data of the facade itself. It is also possible to classify all the observed elements, and it allows to record its condition at time of inspection.

Definitely the proposed methodology will facilitate the collection of information on the status of the built park, in order to record a visual inspection with objective data. According to this design, the data concerning the state of conservation of the facade elements can be easily analyzed in subsequent statistical studies, and they can also be displayed and managed by Geographic Information System platforms.

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