Methodology for the study of the indoor environment, energy consumption and resilience of heritage buildings.

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Abstract
Historic Heritage buildings play an important role in modern societies, as they are a way of keeping your identity safe for future generations. Its conservation challenges the cultural diversity ensurance in a constantly changing world. However, it is an area characterized by the level of energy inefficiency that contributes to a large amount of pollutant emissions. In addition, global warming and the current epidemic crisis make the indoors environmental quality become a very critical point regarding to today's future. It is necessary to understand the adaptation processes and the historic city evolution, to design strategies that make the conservation of heritage compatible with improvements in the inhabitants' quality of life, allowing a sustainable conservation of the historic city. Our main objective is to establish a methodology that identifies the fundamental aspects that affect the environmental conditions and energy conditions of heritage buildings, taking into account their ability to adapt to climate change and their safety of use, within a context of energy efficiency and sustainability. This sample paper describes the formatting requirements for Conference Proceedings, and this sample file offers recommendations on writing for the worldwide readership. Please review this document because some format details have changed related to previous years.

Keywords: Heritage buildings, climatic change, air quality, thermal conditions, constructive characterization

1 Introduction
Historic Heritage buildings are a record mark in cities and play a very important role in modern societies as they are a way of keeping their identity safe for future generations. It is so much that its conservation becomes a challenge to ensure cultural diversity in a world in constant change (Silva, 2019). However, they are also an area where the high level of energy inefficiency contributes to a large amount of greenhouse gas emissions (Prégardien and Marique, 2019).

Currently, there is growing interest in reducing these emissions, required by both European directives and international agreements, which require that improving the performance of historic buildings play an important role in mitigating climate change (Boarin, 2016). Energy rehabilitation has been one of the priorities of the European Union since the signing of the Leipzig Charter in 2007, where it was committed to the sustainable development of cities through the improvement of the energy performance of existing buildings. Despite the fact that this letter did not mention the historical heritage itself, the State Housing and Rehabilitation Plan addresses the historical heritage that needs a particular approach, not contemplated by the existing regulatory framework (EgusquizaOrtega, 2010). According to data collected in the 2019 Population and Housing Census, in 2020, 929 historical complexes and 15 cities were declared BIC in Spain were declared World Heritage Sites, hence the dilemma of energy rehabilitation in pre-industrial building in general, and that of historic centers in particular, is an issue that needs to be approach (EgusquizaOrtega, 2010). If we add to this the current global epidemic crisis, with its consequent and probable health emergency, the environmental quality inside the buildings becomes a very critical point (Pinheiro and Luís, 2020) (NOSTRA, 2020) regarding to the future of today's society.

The valorization and sustainable management of historic centers is a relevant issue for the cultural identity and heritage of European cities (Mazzola *et al.*, 2019). A rational strategy to preserve centers must consider both energy and environmental modernization, even if it is a complex issue that requires interdisciplinary approaches, dedicated diagnostic procedures, and specific tools. For this reason, an integrated method of energy and environmental analysis dedicated specifically to the rehabilitation of historic buildings, green management and maintenance review is necessary (Mazzola *et al.*, 2019).

The problem is that buildings of these characteristics are excluded from renovation activities, and the balance between historical values and environmental sustainability has not been found (Boarin, 2016). However, energy efficiency and the modernization process represent a form of protection of the historic building and not a change in its original material consistency (*Kyrkultsstugan på Skansen - un entorno sensible que requería instalaciones ocultas - Guardar y preservar*, no date) (Boarin, 2016), something that could provide an effective strategy to protect cultural heritage by reducing operating costs and improving environmental quality (Mazzola *et al.*, 2019). And it is that, we find ourselves in a future uncertainty with regard to environmental quality and health inside spaces, which commits us to the generation of healthy environments and to overcome all kinds of prejudices between environmental updating and buildings of equity due to the fact that they play a relevant role in the global reduction of energy use and CO_2 emission (Boarin, 2016). For this, it is necessary to understand the historical processes of adaptation and evolution of the historic city, to design strategies and actions that make the conservation and enhancement of heritage compatible with the improvements in the quality of life of its inhabitants, allowing the conservation of the city sustainable historical (EgusquizaOrtega, 2010). The relationship between matter, structure and construction reality must be understood in order to adequately design rehabilitation options without losing the soul of the heritage (Prégardien and Marique, 2019).

This project aims to identify the fundamental aspects that affect the environmental and energy conditions of heritage buildings, to propose improvements that allow their recovery and exploitation by society, taking into account their ability to adapt to climate change and its safety of use.

2 Study cases

The real estate detected in the city of Seville make up a total of 115 assets in the park of buildings of the public heritage of the Seville City Council. Of these 115 assets, a filtering process has been carried out, focusing the investigation only on heritage buildings, excluding, where appropriate, the different elements of urban heritage (such as walls, mills or others). With which, a total of 85 heritage buildings, dating from the 13th to the 20th centuries, will be the objects of study and application for this study, and that will make up study sample A. In Figure 1 shows images of the buildings of the heterogeneous public heritage of Seville.

From this initial sample, between 8 and 10 statistically representative buildings will be chosen from the subgroups created for their environmental and energy characterization, which will make up the study sample B. Within these subgroups the selection will be made according to the availability shown by their managers for this monitoring.

Figure 1. Real estate of the historical heritage of Seville.

3 Methodology

The methodology includes the development of the following tasks:

- Constructive and spatial characterization
- Characterization of environmental conditions and energy consumption
- Generation of a database
- Analysis of results and classification of the sample

3.1 Constructive and spatial characterization

The constructive and spatial characterization of each of the buildings in study sample A will be carried out, which will allow a first classification to be made. A series of files will be generated that will include information on its location, year of construction, use, construction data, surfaces, etc.

3.2 Characterization of environmental conditions and energy consumption

These tasks will be developed on study sample B. It will consist of in situ measurements of the indoor environmental conditions (temperature, relative humidity, CO_2 concentration and average illuminance) and energy consumption of the study sample buildings. Indoor environmental monitoring will be continuous for a period of 15 days in winter, summer and intermediate season. Measurements will be recorded every 10 minutes creating a database of current status. For this, the WHOLER meters have been chosen that record temperature, humidity and CO_2 with a precision range of ± 3% RH, ± 0.6 ° C, ± 3% of lectyra or ± 50ppm. All indoor air quality measurements will be performed in accordance with ISO16000. The external environmental conditions (temperature, relative humidity and solar radiation) will also be obtained through the National Meteorological Agency of Spain. These measurements must also serve to calibrate the models to be simulated. The buildings will be measured in their current operational condition.

In order to achieve historical energy consumption, a request will be made to the managers of the different selected buildings.

3.3 Generation of a data base

With the information collected in the previous tasks, an open database will be built that can be consulted by the agents in charge of carrying out the rehabilitation / adaptation works of these buildings through the GIS tool. This database will contain the following information: temperature, relative humidity, CO_2 concentration and average hourly illuminance for each of the periods, average daily consumption for seasonal periods.

3.4 Analysis of results and classification of the sample

After the process of monitoring and gathering information to generate the database, the results obtained in the different parameters studied in the properties will be analyzed. The database will be processed with the statistical programs SPSS and STATGRAPHICS to search for correlations between the different variables.

The following benefits will be analyzed:

- **Hygrothermal performance analysis**: The results obtained will be analyzed in relation to the temperature and humidity of the environment in each of the situations.
- **Analysis of environmental quality benefits**: Environmental quality conditions will be studied taking as a characteristic parameter the concentration of CO_2 due to its relationship with possible interior pollutants and as a tracer gas in air renewal measures.
- **Analysis of lighting conditions**: The potential of including natural lighting within buildings and available electrical lighting systems will be analyzed.
- **Analysis of energy consumption**: By analyzing the history of the invoices, the seasonality of consumption and its base consumption will be studied.
- **Existence of systems**: The characteristics and benefits of the different thermal and ventilation systems that currently exist will be analyzed and they will be related to the data obtained on temperature and relative humidity in each of the situations
- **Detection of environmental risks**: Through the data obtained from in situ measurements, information gathering and visual analysis, existing environmental risks in buildings will be detected taking into account their state of conservation, the comfort ranges they provide to users, as well as the environmental conditions for the valuables that in many cases store these properties.
- **Classification:** Once all the analysis of the inspected, monitored and simulated parameters has been carried out, a classification will be carried out that allows the comparison and extrapolation of data in buildings with similar characteristics.

4 Results

In this first part of the work, the constructive and spatial characterization is proposed, as indicated in the methodology. Specifically, cataloging criteria have been obtained, initially based on the chronological time of construction, its morphology and its current use. These criteria are applied in order to obtain building groups and thus establish relationships with the temporal distributions of the enclosure solutions. A constructive characterization process, which will be later than this one developed.

4.1 Chronological Characterization

The chronology of the buildings stock is a determining parameter to know the time in which the heritage buildings began to be built and thus establish historical relationships.

Figure 2 shows the trend of the number of buildings built in the study period, and the percentage that represents each period according to the analysis of the sample group.

If It is analyzed the development of the execution of heritage buildings during the study period, it can be seen that until the twentieth century there is a specific trend of construction, it starts slowly and intermittently, and is not crowded. They are values between 1 and 8% of the study sample. Although it is noteworthy both the eighteenth and nineteenth centuries, where an increase in heritage construction is observed in both periods.

However, the mass construction from the 20th century is striking, comprising more than half the percentage of the sample, specifically 62%. This period coincides with the arrival of the Expo of 29 in Seville, and as it can see the rate of production of buildings of this caliber, it progressively accelerates as this period arrives.

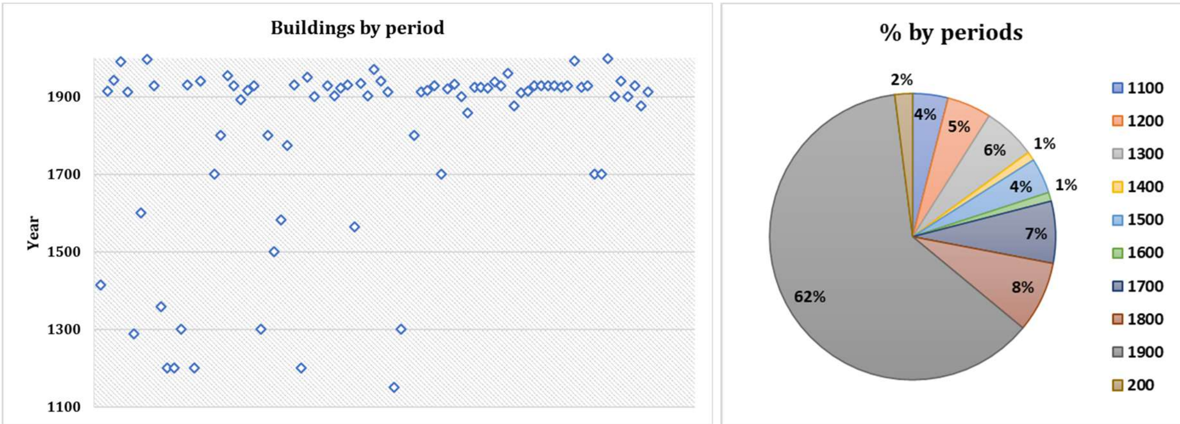

Figure 2. Number and percentage of heritage buildings by periods

It can also observe, as in the period after the Expo, a production stage begins with a decreasing rhythm, generating a stoppage as of 1970. However, in 1990 we began to see an increase in the production of heritage buildings again, which could coincide with the Expo'92 in Seville.

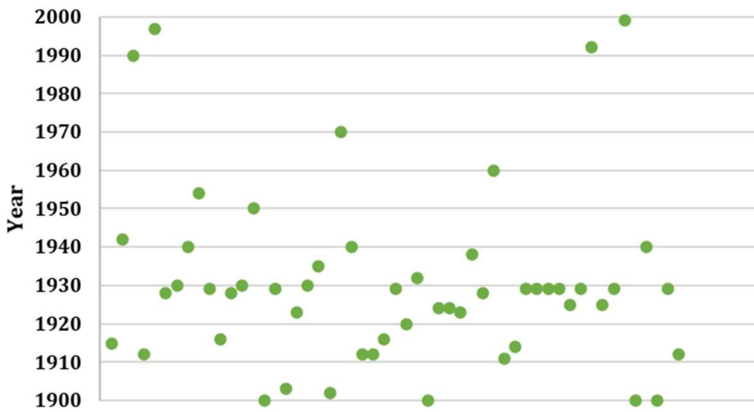

Figure 3. Number of heritage buildings by decades in the 20th century

4.2 Morphological Characterization

The results of the annual characterization analysis of the constructed area of the buildings, in the study period, have been represented in Figure 4. This will be especially relevant to define a possible use and typology.
We can see how as the study period progresses, more buildings with smaller surfaces, between 500m^2 and 3000 m^2, begin to be built. However, it can be seen how in each period certain buildings stand out that opt for more emblematic and representative built surfaces, which reach 8000 m2. Although, in the twentieth century, where it has been verified that there is a greater construction of buildings of these characteristics, it is worth noting the heterogeneity of surfaces that exists.

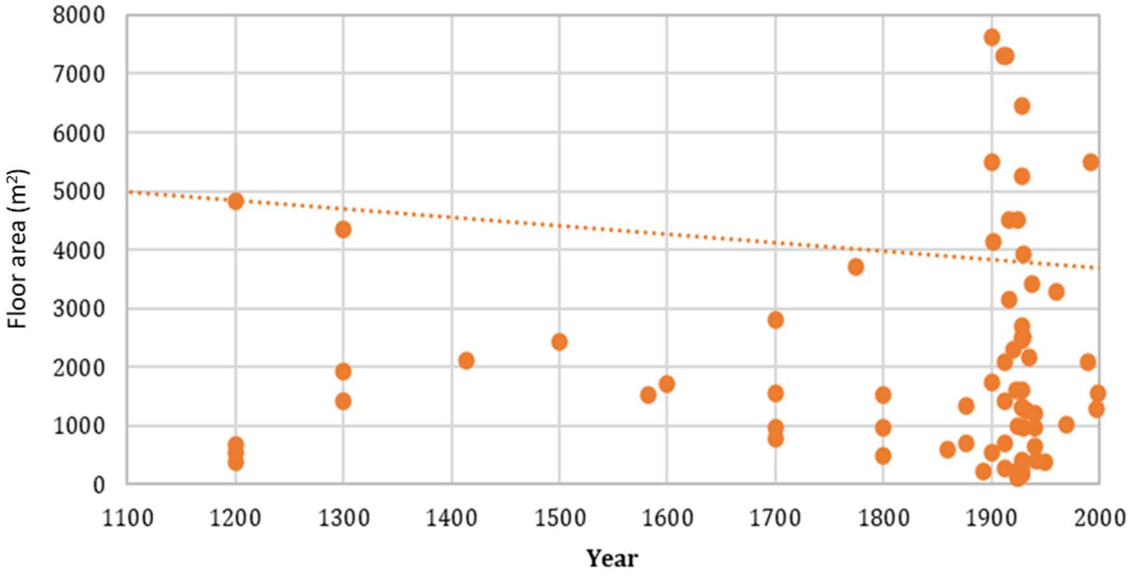

Figure 4. Evolution of the floor area of buildings during the study period

4.3 Utilitarian Characterization

Although many different uses can be identified, we can observe that, basically, 3 main uses prevail: Administrative, Cultural and Unused (Figure 5). A large part of all these buildings in the park have been rendered useless due to their environmental conditions, since they do not provide minimum comfort conditions to users, or in the same way, their structural and constructive conditions do not allow it.

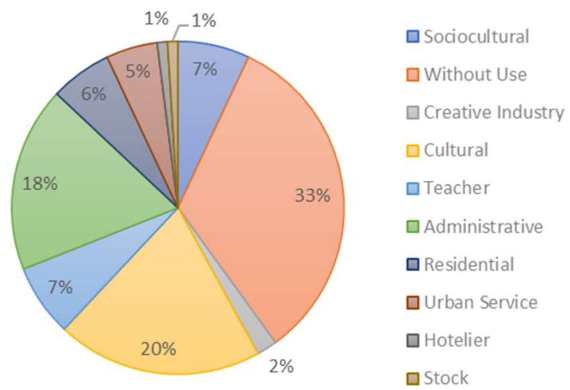

Figure 5. Use of buildings

If we analyze this stock based on the current use to which it is intended, we can know the impact of the different heritage buildings with respect to the easement of the population. For this reason, it can be seen that despite the fact that most of them show inefficient conditions, they are intended to serve as educational buildings, specifically and to a lesser extent, for teaching, socio-cultural or creative industry use.

5 Conclusions

This work includes a first approach towards the application of the proposed methodology, which collects some of the fundamental characteristics of the buildings that make up this period, aiming at the complete cataloging, both spatial and constructive, of the building stock, as the first phase of this methodology.

With the characterization process carried out on the set of heritage buildings studied, several aspects can be concluded:

- Regarding building construction, the slow and intermittent production trend has been verified until the 20th century. However, the 18th and 19th centuries stood out, seeing a growing increase in both periods. Starting in the 20th century, more than half the percentage of the sample was built, specifically 62%, progressively accelerating the rate of production in this period.

- Growth reaches a significant period around 1929, coinciding with the influence of the arrival of Expo'29 in Seville. A growth that can also be seen in the built-up area.

- Finally, according to the utilitarian characterization, it has been found that a large part of the buildings in the park studied are currently not in use due to their comfort conditions, which make the use of the building itself unfeasible.

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