RIVUPH: an Andalusian project for risk analysis in historical cities

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1. Introduction
Reducing risks to cultural heritage is a wide field that includes the analysis of threats at different scales, from a country [Baldi, 1991] to a picture [Bellido, 2013]. As each scenario need a risks assessment, most of the progress and studies are based on collections, archives and museums since 80-years [Anderson and McIntyre, 1983; Lyall, 1988; Waller, 1994; Ashley-Smith, 1999], last risk assessments are based on the management triangle defined by use, conservation and development of the cultural value of collections [Brokerhof, 2006]. The risk management based on cost efficiency on collections is increasing and the methodology for risk analysis in museums and archives is widely studied [Michalski, 1994 and 2007] mainly due to the fact that artworks insurance costs have risen dramatically in the last decade. Opposite, whole monuments or cities are rarely studied under a risk methodology and their analyses are usually based on the assessment of main risks [Stovel, 1998; Vis et al., 2003]. Nevertheless, new approaches are currently being developed to analyse risks for monuments or archaeological sites [Zivkovic, 2012; Paolini et al., 2012], with a huge bulk of data and scenarios, that implies the necessity to simplify models for decision-makers.

The knowledge of risks and hazards are based on the experience and the archive of past and ancient episodes and disasters. Risk management try to use this information to decide the best strategies for preventive conservation [Waller, 2003], which mainly has implied curators and conservation manager until now. RIVUPH is a new approach funded by the Andalusian government (Spain) based on multidisciplinary analysis of environmental risk in historical cities in order to develop town global conservation strategies that can minimize the deterioration of monuments and reduce the cost of isolated interventions with urban plans to carry out town complementary policies between different buildings. The aim of this applied research is to contribute to the preservation of cultural heritage in Andalusia and the development of new methods that could be used in other regions and countries. For this reason, cooperation is carried out with both national and international partners, that warranty the basis for cultural heritage manager decisions.

Under this objective, it is clear that risk analysis need from the evaluation of cultural heritage experts of different fields and the opinion of citizen that enjoy, use the monuments or simple live and stay near them. For this reason, RIVUPH are employing research and social network to validate the opinions of experts and to improve the methodology.

The current crisis leads to prioritize strategies in a town, as the urban unit where territorial policies could be applied, and moreover in a region where the restoration budget is distributed. With this objectives, a new methodology has been developed to evaluate the hazards to different archaeological mo-
numents in the historical center of Merida city (Spain) [Ortiz et al., 2013] and it is in a process of improvement for other kinds of monuments.

2. Methodology
The project initially was based on the methodology of Galán et al. (2006) for the analysis of vulnerability and the model of territorial risk analysis of Pio Baldi (1991) for Italy.

Expert consults and social network analysis have allowed to develop a new criteria based on the Delphi method, that forecast the evolution of a provided situation asking their opinion to seven experts. On our cases this methodology has been used to consider the hazards and vulnerability of the monuments of a city.

With this purpose, seven experts with experience in cultural heritage (one archaeologist, two geologists, one chemist, one architect, one engineer and one environmentalist) have analysed the effects of different damages on cultural heritage monuments. The results have been validated employing social networks with on-line surveys.

This procedure, applied to the vulnerability analysis, has allowed to modify the Leopold’s matrix of double entrance according to the methodology for assessment of environmental impacts developed by Galán et al. (2006). The diagnosis constitutes the qualitative vulnerability matrix that allow visualize and identify the relationships found for the environmental conditions and the conservation degree of the historical centers. The study of weathering forms has been made according to the glossary of ICOMOS (2008) and the standard 1/88 (1990).

The vulnerability index (VI%) for each monument was determined by an on-site study, where the frequency and weathering degree of the deterioration patterns was taken into account [Ortiz et al., 2013].

In this study, the index is evaluated for the predominant lithotype by the equation (1):

$$VI(\%) = \frac{V_x}{\sum_{j=1}^{vdp} v_j x 100}$$

where: VI is the Vulnerability Index, Vx is the evaluation of the damage and vdp is the worst scenario, that is, the maximum value of the weathering forms that could be found in these environmental conditions.

The appearance of weathering forms is set between 1 and 3: where 1 means that it is difficult to detect this weathering form, 2 implies that the weathering form is identified easily and 3 is applied if the pathology occurs at a high rate.

On the other hand, the weathering degree is classified in five relative classes, according to the scale used by Fitzner (2007). Weathering forms Frequency and damage value are combined in order to obtain a numerical value of the intensity of weathering forms in each monument.

The weight of each factor on the vulnerability matrix has been evaluated for monuments as a cognitive maps based on the qualitative diagnosis study.

Finally, the vulnerability index (VI%) is classified by vulnerability degree using classes described by Galán et al. (2006).
The hazards initially was classified in three categories following ICR methodology [Baldi, 1991]: a) the static-structural hazards that included seismic factors, landslides, floods, underground water and geo-technical factors, b) the environmental-air hazards as wind, rain, river erosion, pollution, temperatures cycles and dew point, and c) the anthropogenic factors that include fires, accessibility to the monument, tourist pressure and demographic changes. After two years of the project and the data collected by social network and different collaborations in Spain, Italy and Cuba, the hazards have been increased to include in the analysis the following factors: war and terrorist attack.

The frequencies and intensities of hazards in the historical cities are set up using a relativity scale with five levels. These assessments are developed from the local, regional and national institutions data of weathering, risk, civil protection, environment, urbanism, territorial governance, sociology statistics, tourism, geology, and hydrogeology. Of course, it is near impossible to have every threat in the same city, but this general approach allow to compare the results obtain in different city for a regional make-decisions stake-holders. Meanwhile, each hazard has a frequency and intensity that varies according to the environmental conditions in the different areas of the city.

To evaluate the influence of each hazard and to overlap the factors in the risk map, weighted factors were obtained using the Delphi protocol and consulting the multidisciplinary group of seven experts.

3. Study area
Andalusia, located in the south of Spain, has a privileged situation between Europe and Africa, cradle of settlements and civilizations since prehistoric times. The region of 87,268 km2 is defined in four regions by a cultural point of view [PGBC, 2000]: coast, mountains, meadows and countryside and urban zones. Meanwhile the territorial planning of Andalusia [POTA, 2006] defines regional centers, medium cities, and rural areas. Concentration of monuments is mainly in regional centers, while historical centers are associated to most medium cities, which cultural characteristics depend on environmental conditions.

The first step of the project consist of the risk analyses in medium cities in Seville province as pilot reference to scale the methodology before studying regional centers. The economical and social development of most medium towns, characterized by a territorial organization homogeneous with ability to network their own economy with other medium-sized cities, have allowed to maintain the cultural value of building and historical centers. Four of these cities, Marchena, Osuna, Estepa and Carmona were chosen in this study [Domínguez, 2011; Benítez, 2012; Ortiz, 2012].

Carmona was an Iberian town that was romanised and nowadays maintains the roman urban plan. The two defensive gates of Seville and Córdoba are from this period. Afterwards, Carmona has a relevant role during muslim domination that ended in 1247. During the reign of King Pedro “the Cruel”, Carmona reached a high level in the country region. In this period, the “Alcázar” was developed near the path to Marchena.
Estepa was Ostippo roman town and Istabba Muslim town, which had an important border role. The “Alcazaba” and the wall of Estepa have their origins in the Islamic period, although they have had subsequent modifications.

Marchena was a villa in roman times that was sparsely populated with Muslims due to the large number of olive trees. Walls correspond to the Muslim citadel and during the medieval Christian period (XIV and XV) the town was renewed inside walls and reconstructed, the old Alcazaba was transforme in the Ducal Palace. Sevilla gate (Rose Arch) and Morón gate remember two of the main routes of transport, while Carmona and Osuna gates have disappeared.

Osuna was a Roman city of veterans that was developed in the Muslim period for its strategic location; it became a crucial point for the defense of the border with the Moorish kingdom of Granada.

The four cities have a historical center representative of the human community evolution, which were catalogued between 1963 and 1967. The study areas are around 2.5 km2 and eleven to nineteen monuments have been taken into account in each city. The diagnosis has been based on stones in order to compare the results to improve the methodology. Furthermore, the stones employed in the building are mainly from quarries near the towns and their properties are well-known [Bello and Martin, 1992; Ortiz et al., 1994, 1995, and 2008].

4. Results and discussion
The study of the vulnerability in around seventy monuments in Seville province (Andalusia, Spain) has allowed develop a cognitive diagram of relationships between different variables and the vulnerability index to improve the method of risk analysis. Foundation, structure and constructive system has the most clear influence in the vulnerability index (weight 1), as these variables could produce the collapse of the monuments and the total or partial lost of the building. Physical-chemical characteristics, texture and fire-resistance define the conservation degree of the materials and have a medium influence (weight 0.6), which is mainly dominated by the quality of materials. Aesthetic appearance has the lowest influence of the variables (weight 0.3); in spite of it is the first pathology to be detected. The range of materials and design of the constructive system are also being evaluated. The vulnerability has near the same weight of the hazards according to Delphi analysis. The scheme of hazards and vulnerability relationship is summarised in the fig.1.

The vulnerability identification matrixes of the monuments are mainly due to the impacts associated to erosion (change of temperature and wind pressure), pollutants, interventions and vandalism in the four cities. Meanwhile, some weathering forms in Carmona and Estepa highlight stability influence. Moreover, the most common stone in the four cities are calcareous sandstones, calcarenites and limestones that are very vulnerable to the effect of traffic in Historical Centers.

The classification of the vulnerability index of the monuments studied is showed in table 2.
Most of the monuments exhibit a very low or low degree of vulnerability (88%),
what means vulnerability index less than 25%. These monuments should be under a preventive conservation plan with minor interventions. The “Alcazar” of Carmona has the highest vulnerability index (60%) and seven of the monuments present moderate vulnerability. The vulnerability index comparisons reflect that the “Alcazar” of Carmona need the first project of intervention and continuous checking, following by those seven monuments with moderate vulnerability.

The overlap between the vulnerability and the main threats provide further information about the intervention program and the preventive conservation actions. The highest values of the risk in the studied town are found in Estepa and Carmona, which are dominated by the hazards of landslides. The presence of clay minerals around the edge of the hill is the cause of this static-structural risk. Furthermore in Carmona, the risky area is just where the Alcazar is located, the risk of landslide added to its high vulnerability index (60%) worsen the situation and increase the necessity of special conservation with inspections and checking.

The traffic is an environmental hazard that has to be taken into account. This hazard is enhanced by the calcareous stones employed in most of the building. For this reason, vehicle traffic reductions should be mandatory near the monuments that are catalogued in the four cities. The four cities require an urban plan for car traffic control to avoid drive near the main monuments, so decrease the weathering due to cars pollution.

Finally, the detailed evaluation of urban plan in the city of Marchena (Ortiz, 2012), as a theoretical positive factor, evidence the lack of building that should have been protected (figures 2 and 3). The public administrations were informed of this irregular situation in 2012, but unfortunately we do not have evidence that any action has been taken since them, so it is necessary to improve the instruments of controls and the inspections.

The Vulnerability matrix methodology is an economic and effective tool to eva-
5. Conclusions
This new procedure provides protocols to develop policies for making decision when you have a monumental area to preserve as historical centers. This methodology allows compare risk between different cities to analyse strategies for cultural heritage conservation in a region, or inside a city, to evaluate the hazards of different zones in order to plan interventions. The vulnerability indexes obtained combined with the risk assessment, while limited in accuracy, are coherent and allow comparison between diverse monuments. This enables Public Administration to make decisions for preventive conservation and prioritize the restoration resources of a city or even a region.

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