

Filipa Almeida * and Ana Lúcia Virtudes

ICT for smart evaluation of vernacular architecture in a stilt-house village

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Abstract: Vernacular architecture typologies, such as wooden stilt-houses, have been threatened by the vulnerability to conservation status degradation. This problem is not an exception in Portugal, where the few remaining examples have been neglected, with the disappearance or abandonment of almost all buildings, damaging architectural and urban spatial features. This legacy is rapidly disappearing, weakening the European cultural map.

This research presents the results from a smart evaluation method using an ICT (information and communication technology) platform designed for the smart evaluation of wooden stilt-houses, considering their conservation status. This platform was used in the five remaining stilt-house villages still existing in Portugal including about 90 buildings and 300 inhabitants, located along Tagus river banks. This article refers to one of these case studies, the village of Escaroupim, which was chosen because it is the most urban space in between all of them.

On one hand, the results are an exhaustive survey of vernacular buildings, useful as guideline for spatial strategies and instruments to protect this legacy. On the other hand, it can be used in other similar wooden buildings, to check their conservation status and therefore to define best rehabilitation actions.

Keywords: ICT, smart evaluation, vernacular architecture, wooden stilt-houses

1 Introduction

The wooden stilt-houses, as a typology of vernacular architecture, have been threatened, all over the world, by the vulnerability to degradation processes [1, 2].

In Portugal, this problem affects the remaining five stilt-house villages (Patacão de Cima, Caneiras, Palhota, Escaroupim and Lezirão) along Tagus River banks (Figure 1). This legacy has its roots in the 1860s, in a migratory movement of the fishing community coming from the Central West Coast to this river banks. They were called Avieiros.

From about 80 Avieiros settlements of vernacular architectural wooden stilt-houses, nowadays there are only five remaining villages, including Escaroupim, which is the most urban among them.

The decline of fishing has led to the search for new sources of income in the crops and later in the cities, decreasing the number of inhabitants [3–8]. Consequently, this process triggered a set of urban and architectural weaknesses (with the total abandonment or disappearance of some villages) that persists so far. This scenario worsens by the spatial planning rules defined for these settlements which are making complex and difficult the preservation of wooden stilt-houses of vernacular architecture, their urban morphology or their spatial relationship with the waterfront [9, 10].

The Avieira houses comprise two types of vernacular architecture: the stilt-house which is the dominant type and the one-story house which corresponds to the non-dominant type. The Avieira wooden stilt-house [11–14] is a parallelepiped of a single floor (length bigger than the height on the facade) sustained in wooden stilts or tree trunks, later replaced by concrete stilts. The roof, on rod or tile, has two slopes with an eave oriented to the front.

In constructive terms, the stilt-house system is in grid, with the body of the building independent of the piling. The coating of the exterior walls is made with wooden boards set vertically, linked by narrower vertical wood joints and placed over the floor built over stilts.

These buildings are painted with cheerful colours with a predominance of green, red, blue and orange. An exterior wooden staircase provides access directly to the main

*Corresponding Author: **Filipa Almeida** : Department of Civil Engineering and Architecture - University of Beira Interior Calçada Fonte do Lameiro, Edifício II das Engenharias, 6201-001 Covilhã, Portugal

Ana Lúcia Virtudes: Department of Civil Engineering and Architecture - University of Beira Interior Calçada Fonte do Lameiro, Edifício II das Engenharias, 6201-001 Covilhã, Portugal

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entrance or to a balcony on stilts, running on the main façade, covered or not by the roof overhang (porch) and protected with wooden railing.

In urbanistic terms, the main features of these settlements are the following:

1. The river as defining element and limit of urban morphology;
2. A certain diversity of activities, from housing to commerce or facilities, including in one of these villages (Caneiras), a small church;
3. The urban consolidation of the villages, despite the spatial planning instruments for these places, classifying them as non-urban areas.

Despite the continuous abandonment and neglect of these settlements, the remaining buildings are now the benchmark of an era and a vernacular architecture, which makes it important to study, identify and be made known for future generations.

In order to contribute to the definition of intervention strategies (conservation and rehabilitation), reducing their vulnerability to degradation processes, this research is focused on the analyses of the results from the application of a smart method using an ICT platform designed for the evaluation of wooden stilt-house features, considering the conservation status of the buildings. This proposal relates to a layered architecture in cloud database [15]. The ICT platform allows the compilation and processing of data collected in visual inspection, establishing a comparative analysis of the results not only between buildings but also between different villages. For each building, there is an automatic generation of Individual Record which gives two types of information, considering the points and the weights given to each constructive element and group of elements: Analysis 1 – Need for immediate intervention, with the alert indicators activated (in red) and the corrective actions to make; Analysis 2 – Status of building conservation, with data graphs about the level of structural quality (ECe), non-structural (ECne) and global (EC), considering the Anomalies Index of the groups of constructive elements.

The obtained results from the village of Escaroupim, totals 15 vernacular architectural buildings. In this settlement, the previous rurality usually present in these Tagus villages is being diluted. However, it was also this transformation process that has kept the village alive, adapting the buildings and the urban mesh to the contemporary demands.

2 Developing smart evaluation of vernacular architecture

The working methodology used for the definition of evaluation method of vernacular architectural wooden stilt-houses of river banks in Portugal, regarding the status of building conservation, comprised three working steps:

1. Evaluation criterion;
2. Weightings scale;
3. Application tools.

Evaluation criterion: the proposed criterion for evaluating the status of each building conservation is the severity of the anomalies affecting its constructive elements.

The levels of anomalies followed five measurement intervals, according to a descending scale, from the best conservation level to the worst: very slight (with 5 points), slight (with 4 points), average (with 3 points), serious (with 2 points) and very serious (with 1 point). In order to facilitate the allocation of building anomaly levels, a Score Grid was developed including a set of complementary records (one for each constructive element), with several indicators about how to select the applicable element and guidelines for its evaluation, within each level of the rating scale.

Weightings scale: the defined weightings scale has six scores, following a descending scale, according to the importance of each constructive element / group of constructive elements in building performance, and its relation with other constructive elements / group of constructive elements, from the highest level (with 6 points, corresponding to a very important element) to the lowest (with 1 point, corresponding to the least important element). Regarding the groups of constructive elements, for evaluation of the status of building conservation, this methodology uses the following scores: 6 points for structural condition, 5 points for coatings / finishes, 3 points for spans (such as doors and windows), 3 points for other elements such as chimneys, and 2 points for non-structural walls. The defined number of points (Pt) of each constructive element is the result of the product between the number of points associated with the anomaly level (n) and its weightings (Pd):

$$Pt = n \times Pd \quad (1)$$

The final result of the building evaluation depends on the anomalies index (IA) of each group of constructive elements. Therefore, it varies between 1 to 5 and it results



Figure 1: Avieiras villages located along the Tagus river: Caneiras, Escaroupim, Palhota, Lezirão e Patacão de Cima.

from the quotient in between the points sum ($\sum Pt$) and the weightings sum ($\sum Pd$) given to constructive elements of the group:

$$IA_{group} = \frac{\sum Pt}{\sum Pd} \quad (2)$$

Whenever one constructive element is not applicable to a particular building, its weighting is not considered in the previous equation.

This evaluation method allows to get three levels of indicators: the structural quality level (EC_e), the non-structural quality level (EC_{ne}), and the general (structural and non-structural) quality level (EC). In this sense, the EC_e reflects the status of building structure conservation, regarding only this group of elements “EA – Structural Condition”. This corresponds to the IA of the group and its conversion in percentage, according to the following rule:

$$\frac{(EC_e \times Pd_{EA} - 6) \times 100}{24} \quad (3)$$

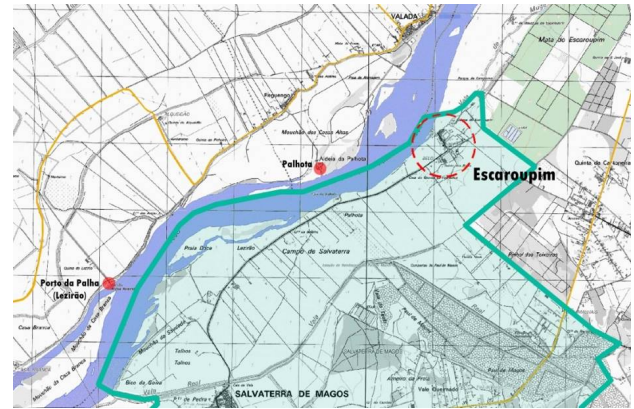


Figure 2: Escaroupim: accessibilities (road infrastructures). Graphic scale. Adapted from Carta Militar de Portugal, 1:25 000, 2007, Folha 377, série M888, accessible in IGEOE, Lisboa, Portugal.



Figure 3: Urban morphology of vernacular village of Escaroupim (IGP, 2007; Almeida, 2015).

The EC_{ne} reflects the status of non-structural elements conservation and considers all the groups, except the “EA – Structural Condition”. It varies in between 1 to 5 and it results from the quotient between the aggregation of the products of IA of the mentioned groups and their weightings (Pd) and the weightings of all groups sum, according to the following equation:

$$EC_{ne} = \frac{[(IA_{EB} \times Pd_{EB}) + (IA_{EC} \times Pd_{EC}) + (IA_{ED} \times Pd_{ED}) + (IA_{EE} \times Pd_{EE})]}{(Pd_{EB} + Pd_{EC} + Pd_{ED} + Pd_{EE})} \quad (4)$$

Once again, whenever one group is not applicable, its weightings are not considered in the previous equation. The conversion of EC_{ne} in percentages follows the next rule:

$$\frac{(EC_{ne} \times (Pd_{EB} + Pd_{EC} + Pd_{ED} + Pd_{EE}) - 13) \times 100}{52} \quad (5)$$

In order to determine the EC , there is need to consider that the structural part (EC_e) and the non-structural part

(EC_{ne}) of the building, represent 50% each, being calculated in percentage, according to the following equation:

$$EC = \left(\frac{(EC_e \times Pd_{EA} - 6) \times 100}{24} \right) \times 0.5 + \left(\frac{(EC_{ne} \times (Pd_{EE} + Pd_{EC} + Pd_{ED} + Pd_{EE}) - 13) \times 100}{52} \right) \times 0.5 \tag{6}$$

The final result is converted into a scale of five qualitative levels: [0-30[for very bad condition i.e. physical ruin with no rehabilitation chance; [30-50[for bad condition i.e. buildings in economic ruin implying a deep rehabilitation action; [50-70[for average condition i.e. needing repair and replacement of constructive elements; [70-90[for good condition i.e. needing small repairs and enhance actions; and [90-100] for very good condition i.e. buildings with no need of repairs. These intervals were defined based on an experimental application of this method to a previous testing sample of buildings, which allows us to check, improve and validate it.

The need for immediate intervention in the building is the result of very serious anomalies that are putting in danger the safety of people or that have no safety guaranties of building use conditions (as shown in Figure 6).

Application tools: this evaluation model comprises the design of two application tools. One is the diagnosis record, including the application instructions, containing the fill mode of each section, the type of information to be collected and a scoring grid for the status of building conservation. The other is the computing programme software, an ICT platform that allows the compilation and processing of data, with the advantages of allowing a comparative analysis of the results, not only between all buildings but also in between several villages.

3 Urban consolidation of the vernacular village of Escaroupim

In Escaroupim, there is a village located 7 km north from Salvaterra de Magos (Figure 2), with 131 inhabitants (Census 2011). It distances from the river between 50 m (downstream) and 190 m (upstream).

This village evolution is characterized by the morphological linearity of the historical nucleus up to the 1950s. Since then, the combination of fishing and other activities led to an urban expansion process into the territory reflecting a dichotomy between the vernacular architectural matrix of the wooden stilt-houses and the new buildings. The historical nucleus has 15 houses of vernacular archi-

ture, and is organized in two alignments of buildings (Figure 3 and 4).

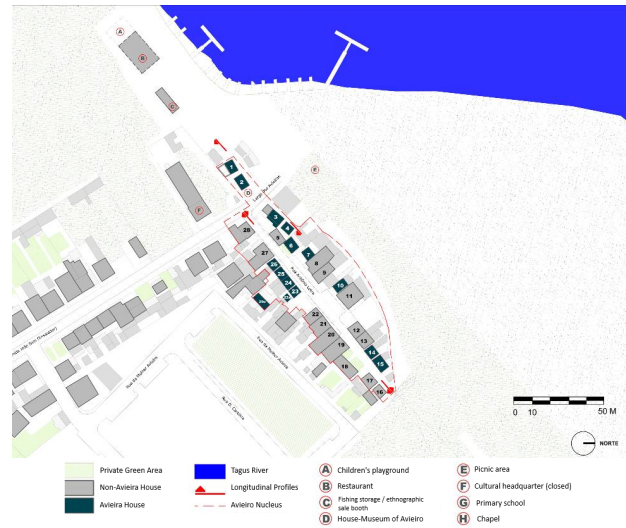


Figure 4: Escaroupim: characterization plan of the avieiro nucleus.

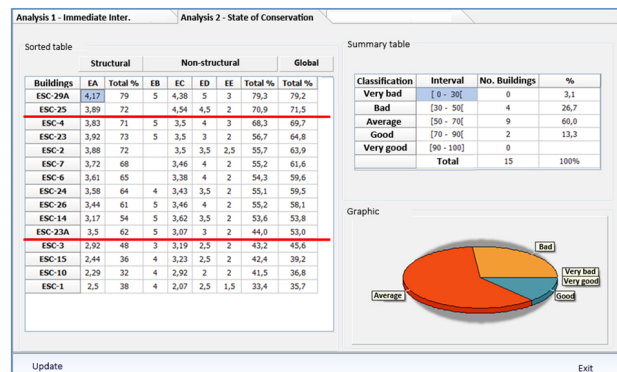


Figure 5: ICT platform application for evaluation of status of wooden stilt-houses conservation, in Escaroupim.

In architectural terms, the houses in the historical area, correspond to the vernacular matrix, while in the expansion area, majority of building structure comprises only brick houses, with marble tiles and higher volumes. However, it was also this transformation process that has kept the village alive, adapting the buildings and the urban mesh to contemporary demands. Escaroupim is considered the most urban village among the vernacular settlements of Tagus river banks.

In this village the waterfront is the space of confluence of local community, where many actions related to leisure and tourism are taking place. Here there is a Museum in a wooden stilt-house of vernacular architecture, which was



Figure 6: ICT platform application for evaluation of status of wooden stilt-houses conservation, in Escaroupim: a. vernacular stilt-house village of Escaroupim; b. the worst case of status of building conservation (corresponding to the wooden stilt-house no. 1); c. the best case of status of building conservation (the single-story house no. 29a).

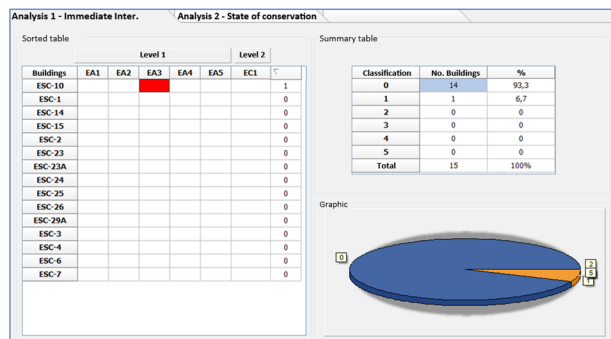


Figure 7: ICT platform application for evaluation of status of wooden stilt-houses conservation, in Escaroupim: the identification of needs for immediate intervention in vernacular wooden stilt-houses.



Figure 8: ICT platform application for evaluation of status of wooden stilt-houses conservation in Escaroupim: the wooden stilt-house identified by no. 10, is the most problematic case.

rehabilitated to this new use, and there are other facilities including a picnic park, a children’s playground, a restaurant and a shop selling ethnographic products.

This sense of contact with nature nearby the river and the environment potentiality is increased by a forest belonging to the national authority, with a camping area used as recreational park. In front of the village, in the river, there is a small island where it is possible to observe a colony of herons, among other species of birds, which is a source of attraction for many researchers and bird-watchers. At this place, there is also a wide strip of sand that in summer, becomes a river beach.

4 Smart method application for evaluation of vernacular architecture in Escaroupim

In the village of Escaroupim, located in the municipality of Salvaterra de Magos, there are so far 15 wooden houses of vernacular architecture, localized in the historical nucleus of this urban settlement, which totals 17% of all vernacular houses, still remaining in the five villages as a whole. Eight of these buildings have the architectural typology of a stilt-house, and seven of them have the architectural typology of a single-story house, which totals 13% and 25% respectively, of each one of these typologies of vernacular architecture, considering the five villages.

Regarding the status of buildings conservation (Figure 5), the results show that more than a half (60%) of the vernacular houses, including five belonging to the typology of stilt-houses (corresponding to buildings no. 2, no. 4, no. 23, no. 23a and no. 24), and four belonging to the typology of single-story houses (which are buildings no. 6, no. 7, no. 14 and no. 26) are in the ‘average condition’ level.

The other buildings are classified in the ‘bad condition’ level (26,7%) including three of stilt-houses typology (no. 1, no. 3 and no. 10), and one belonging to single-story house typology (no. 15), located in the west alignment of the village (Figure 6a). There are some buildings (13,3% of them) in ‘good condition’ level including two single-story houses (no. 29a and no. 25), which are located on the east alignment of the village.

The wooden stilt-house (Figure 6b) in worst condition, is the building identified by no. 1, degraded not only in coatings and finishes (EC), but also in other non-structural elements (ED).

On one hand, the smart evaluation method shows that wooden stilt-houses are more degraded (in ‘very bad

condition' level) than wooden single-story houses, corresponding to 38% and 14% respectively.

On the other hand, from the ICT platform application to the Escaroupim wooden stilt-houses, it is possible to conclude that four buildings, which represent 27% of the total, require deep rehabilitation actions, due to their degradation (which is the case of buildings no. 1, no. 3, no. 10 and no. 15).

Finally, this smart method shows that the wooden stilt-house identified by no. 10, which is an empty building, has the warning indicator active, related to structural horizontal elements (Figure 7). Therefore, this is the most problematic case, needing immediate intervention (Figure 8). In this village, there are no houses in 'very bad condition' level in terms of status of buildings conservation.

5 Conclusions

Considering the weakness and vulnerability of wooden buildings of vernacular architecture all over the world, such as wooden stilt-houses of river banks in Portugal, the result is permanent and continuous disappearance of this legacy. This degradation process is due to their very bad or bad status of conservation.

The main challenge of this research was to design a method, using a software computing programme, regarding the features of wooden buildings of vernacular architecture, having as case studies stilt-houses of river banks.

On one hand, the novelty of this evaluation model adopted in these buildings as a diagnosis methodology is the fact that it will be suitable for the vernacular architecture. On the other hand, the considered ranges of the five levels of status of buildings conservation do not exhaust the entire hypothesis, and the sample (or the case studies) can be extended to other buildings, in order to include, for example, houses in a 'very good condition' level.

This model is flexible given that it allows distributing the buildings by the other levels. Consequently, its advantages are the facts that it can be used and tested in other buildings all over the world with similar vernacular architectural features and it can be used and tested in the same buildings in a period of time, in order to re-evaluate their conditions at regular intervals, checking their levels of degradation.

Future rehabilitation strategies for vernacular stilt-houses and Tagus river villages in particular, pass through the reverse of the degradation processes. In this sense, it is essential to apply an external diagnostic methodology, such as the one created specifically for these houses

which allowed the evaluation of the status of buildings conservation, resulting in the definition of the needs and priorities for action. This methodology aims to contribute by informing and supporting the decision-making process about where, when and how to act, allowing the establishment of correlations between houses and villages and the re-evaluation of the same case studies, while updating the information after rehabilitation.

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