Multi-criteria analysis of rehabilitation techniques for traditional timber frame walls in Pombalino buildings (Lisbon)

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A B S T R A C T

This research aims to evaluate the intervention techniques currently adopted for the traditional timber frame wall, using a case study in downtown Lisbon. Different rehabilitation solutions were identified and assessed through a multi-criteria decision analysis using dedicated software (M-Macbeth, Measuring Attractiveness by a Categorical-Based Evaluation technique).

Five evaluation criteria, i.e. material compatibility and permanence, structural reliability and authenticity, and visual-tactile appearance, were selected for this specific context. A multidisciplinary panel of experts in conservation science were consulted for defining the performance descriptors, evaluation levels, and weightings of these criteria.

Results show that Macbeth is a useful decision-aid capable of handling multiple outputs generated from qualitative expert judgments. Lastly, the predominance of five best-scoring interventions within three design-related scenarios is discussed.

1. Introduction

Building rehabilitation is a challenging task due to conflicting priorities pursued by multiple stakeholders, e.g. experts in conservation science, municipalities, owners, and contractors. In fact, safeguarding the authenticity of historic construction can conflict with the reliability of the authenticity work, budgetary constraints, and/or limitations imposed by the presence of occupants in the building.

When a variety of non-numerable and non-homogeneous criteria have to be taken into account for the selection of the best solution among several options, the decision-making process can be supported by Multi-criteria Decision Analysis (MCDA) \cite{1,2}. However, although MCDA models can guarantee transparency and interactivity, these methods are rarely applied for questions regarding the preservation of historic structures, e.g. for the evaluation of cultural assets regarding solutions for their reuse \cite{3} or for the assessment of different rehabilitation techniques.

This research presents a straightforward methodology to guide decision-making related to the preservation of timber-framed heritage in seismic-prone zones. The evaluation process is addressed by dedicated software (M-Macbeth, Measuring Attractiveness by a Categorical-Based Evaluation Technique) capable of handling multiple outputs generated from qualitative expert judgments \cite{4,5}. This study investigates the opportunities offered by multi-criteria analysis in analysing a case study of buildings in downtown Lisbon (so-called Pombalino buildings).

Following its devastation by earthquake, fire, and tsunami in 1755, the downtown of Lisbon was reconstructed in situ by employing a set of advanced anti-seismic techniques \cite{6,7}. This building stock covers an area of 23.5 ha and consists of 62 blocks and 430 building lots. Most of these buildings have remained unchanged in terms of number, volume, type of allotments, geometry of the facade as conceived in 1756–1758, while the degree of authenticity of each plots greatly varies. Many have undergone structural alterations; these include enlarging the openings at the groundfloor, adding extra floors, demolishing internal structures, and introducing new systems (lifts, staircases, overhanging structures to the rear). In few cases, major alterations of the entire volume were executed especially during the first decade of the 20th century.

The Pombalino structural system is based on a hyperstatic model composed of stone masonry external walls and a set of internal load-bearing timber frame walls that are connected to wooden floors by means of pre-carved posts or by nailing posts to beams embedded into the external facade (Fig. 1). The type of the connections greatly varies according to the dating of building execution. The most common joints used are the half-lap joints held in place by one or two nails, and less...
frequently, dovetail or mortise and tenon joints [8, 9].

Above thick masonry pillars and stone vaulted ceilings of the ground floor, these three-dimensional timber frames above the first floor, reinforced by wooden cross-bracing components (10 × 10 cm or 10 × 8 cm), are designed to withstand seismic actions through the ductile behaviour of the joints and the satisfactory interlocking of each construction component (i.e. interaction of timber framework, joints, and infill) (Fig. 2). The ductility of the joints is directly related to the ability of the structure to deform nonlinearly without significant loss of strength, whereas the interlocking increases the maximum load and stiffness of the connection [10].

Pombalino construction, which was systematically employed from the late 18th century onwards in Lisbon’s other districts as well, is remarkable evidence of a collective effort to reformulate time-tested local techniques (as testified by Medieval and Renaissance ordinary buildings in Portugal) and effect a comprehensive renewal of the city at urban, architectural, and structural levels [6, 11].

Regardless of the significant value of these buildings and their central location, a remarkable decrease of occupancy was continuously registered from 1911 to 2011, with a loss of almost 90% of the inhabitants who initially lived in these houses [12]. This process of desertion was reflected in all the historical districts of the city, and it was followed by a considerable neglect of these constructions.

Countering this trend, significant real estate investment has been fostered in the last five years by the centrality of this building stock and new market demand linked mostly to the increase in tourist flow. Many of these buildings, previously empty or rented at very low prices, have been sold in recent years to private companies to accommodate restaurants and stored in the ground floor and hotels in the upper floors. The Portuguese government approved a special legal regime applicable from 2014 until 2020 devoted to the rehabilitation of these buildings with the aim of reducing the cost of interventions and fostering urban
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