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Building rehabilitation versus demolition and new construction: Economic and environmental assessment

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ABSTRACT

Since the end of the twentieth century, discussion on dwelling rehabilitation versus its demolition and new construction has been steadily increasing in intensity, which is especially due to the necessity for the regeneration of urban centres. However, rehabilitation is not always considered the most economical solution, and demolition and new construction may constitute a better option. In the present work, a multi-family building in Seville, Spain, is used as a case study. After having suffered damage from a construction failure, it is assessed for its complete rehabilitation. Defective maintenance has worsened the bad condition of the building. A model is proposed, from the project budget perspective, that allows the environmental (Ecological Footprint indicator) and the economic (project's bill of quantities) assessment of the recovery of the dwelling. In the case study, the rehabilitation Ecological Footprint and the project cost are 0.06 gha/m^2 of floor area (457.22 EUR/m^2) and 0.14 gha/m^2 (576.33 EUR/m^2) for a new building on the same plot, respectively. It can be deduced that, even with a severely damaged building, the repair and retrofit work incurs a lower economic and environmental impact than that of the total replacement with a new construction.

1. Introduction

Discussion on dwelling rehabilitation versus its demolition and new construction has been increasing in intensity since the end of the twentieth century, especially due to the necessity for the regeneration of urban centres caused by the great migration from rural to urban areas (Denhez, 2007; Laefer and Manke, 2008; Rakhra, 1983). In the European Union, entire neighbourhoods were re-built shortly after the Second World War. Now they fall short of meeting current needs (insufficient and outdated installations, poor insulations, obsolete equipment, among others), therefore neighbourhoods formed by these types of dwellings are under continuous threat of mass demolition (Power, 2010, 2008). For over a decade, it has been predicted that building rehabilitation would be the dominant activity in the construction sector (Kohler and Hassler, 2002).

Financial aspects tend to tip the balance towards building rehabilitation rather than demolition and new construction (Itard and Klunder, 2007), except in those cases where the building is so damaged that rehabilitation costs reach the levels of new construction costs. Studies usually focus on the potential for energy savings in buildings once renewed (Goldstein et al., 2013), but there have been suggestions for the evaluation of these savings along with other aspects, such as the increase in value of a building or the improvement of the conditions of its components (Martinaitis et al., 2004; Zavadskas et al., 2008). Other proposals are more detailed and deal with energy prices, the hypothesis of an increased use of renewable energy, maintenance costs, or financial interest rates (Morelli et al., 2014). However, the need to include not only economic, but also environmental and social aspects in this analysis has increased over time, as these factors are all part of the concept of sustainability (Thomsen and van der Flier, 2009).

In this paper, the rehabilitation of a building under emergency conditions after a construction failure is assessed in detail. The analysis incorporates the improvements necessary to make a building habitable, as well as the repairs and maintenance needed to improve the comfort of tenants (Ferreira Sánchez, 2015). In order to take into account as many variables as possible in this difficult decision of rehabilitation vs. demolition and new construction, a model is proposed from the project budget perspective that allows both the economic (project's bill of quantities and budget) and environmental (Ecological Footprint indicator) assessment of these two options.

The Andalusian Construction Cost Database (ACCD) (Andalusia Government, 2014) is used for the cost assessment, and new

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rehabilitation costs, which are not included in the database, are created using its work breakdown system. For the environmental impact assessment, the Ecological Footprint (EF) indicator (Wackernagel and Rees, 1997) is employed. The EF is the amount of land that would be required to provide the resources (grain, feed, firewood, fish, and urban land) and absorb the emissions (CO_2) of humanity. The EF, along with the Carbon Footprint, have become two of the most widespread indicators thanks to the simplicity of their concept (as compared to LCA assessment) and their ability to place sustainability on the agenda. However, due to the major simplification of such an extremely complex process as that of the environmental impact on Earth caused by humans, certain flaws regarding its scientific value have been highlighted by several authors (Fiala, 2008; Grazi et al., 2007; Van Den Bergh and Verbruggen, 1999). Despite these flaws, EF has been employed in the development of various assessment systems for construction projects such as: structural sustainability in BIM (Oti et al., 2016), dwelling construction (Bastianoni et al., 2007; González-Vallejo et al., 2015a; Solís-Guzmán et al., 2013), urbanization of rural land (Marrero et al., 2017), and building maintenance and cleaning tasks (Martínez-Rocamora et al., 2016a).

On this basis, the proposed model will assess the feasibility economic and environmental of the renovation of a building that is facing demolition, specifically analysing a case study of 40 social housing dwellings with severe structural damage located in the city of Seville. The authors' previous models are employed for the assessment of the economic cost and EF of construction and urbanization processes (Freire and Marrero, 2014; González-Vallejo et al., 2015b; Solís-Guzmán et al., 2013).

2. Literature review

Regarding the topic of this study, Bullen and Love (2010, 2011) came to the conclusion that the three key criteria for decision-making in cases of renovation versus demolition and new construction were the investment costs, the building conditions, and the regulations. Other factors, such as environmental, economic and social principles, were relegated to having less influence.

Itard and Klunder (2007) studied the environmental effects of the life cycle of buildings in terms of time, concluding that, in a scenario in which a building lasts 100 years, the total energy consumed over the lifetime of the building is higher if the dwelling is either kept as-built or demolished and newly constructed, and lower if refurbished. Reconstruction poses a significant environmental impact, but also offers opportunity for the improvement in the energy efficiency of the building.

Along the same lines, Verbeeck and Cornelis (2011) analysed the renovation versus demolition and new construction of a portion of the dwelling stock in Belgium under different scenarios, from an energy, economic and environmental point of view. They concluded that the annual energy savings did not justify demolition and new construction, and that this option would only make sense if the building were in an extremely poor condition for habitation and if the rehabilitation were going to incur a major cost. From the environmental point of view, they conclude that demolition and new construction is not necessarily a worse option than renovation. The energy savings that can be achieved are greater when replacing the building with a new construction where waste reuse and recycling is maximized in demolition work.

Dobbelsteen et al. (2004) designed a methodology for the simplified mathematical analysis of the environmental impact of renovation versus demolition and new construction. This method is based on the allocation of specific environmental costs and of annual environmental costs, with the former relating to the construction, demolition, and possible renovation, and the latter to the costs of the consumption of energy and other resources on an annual basis. In their model, it is assumed that the renovation or new construction should lead to a reduction of annual costs, since the renovated (or new) building should be more energy efficient.

One of the most interesting alternatives to demolition and new construction consists of the reuse of existing buildings and their expansion. Thus, the potential waste generation and consumption of resources are reduced, while the reuse of materials is maximized (Chapman et al., 2003, 2002, 2001). Logically, this solution is conditioned by the feasibility of reuse of the building components. Laefer and Manke (2008) conducted a study on the partial or total reuse of buildings in which it was concluded that reuse can produce savings of 4% to 65% depending on the utilization of the existing building. In addition, new buildings use four to eight times more material resources than the equivalent rehabilitation (Ireland, 2008; Yates, 2006).

According to Sezer (2012), the existing methods of analysis of the environmental impact of buildings focus on the construction of new buildings. In these models, the variations in productivity, efficiency and short- and long-term consequences in the rehabilitation work are not covered: hence the need to create arises for the creation of a methodology for the quantification of resources and for the calculation of environmental impact that is applicable to rehabilitation.

The previous models of the authors are used for the evaluation of the economic cost and EF of the construction and urbanization processes (Freire and Marrero, 2014; González-Vallejo et al., 2015b; Solís-Guzmán et al., 2013). The model proposed in this paper will evaluate for the first time the renovation of a building that faces demolition through the evaluation of economic and environmental aspects, making necessary a new approach that replaces normally used unitary costs of constructions project by complex costs; the last are completed buildings elements (facades including its finishes, foundations including auxiliary's elements, etc.), this way deteriorated elements con be analysed as a construction project.

3. Methods and materials

The proposed model aims the technical, economic and environmental evaluation of the rehabilitation of buildings that are facing a demolition and new construction. The model is divided into three phases. First, a rehabilitation cost database is created that allows the economic evaluation of this type of work. Second, the evaluation of the environmental impact is carried out by means of the adaptation and application of the HE model to the rehabilitation of buildings. Third, an integration process of the economic and environmental costs is carried out, through the creation of what has been called the resource quantification bank, which consists of disaggregating the different construction units into machinery hours, labour hours and kilograms of materials; this covers all the activities defined in the project budget, and in this way, the data necessary for the calculation of the HE of the rehabilitation of buildings is obtained. The resource quantification bank is the calculation engine of the evaluation model developed. The great diversity of activities included in the cost assessment and the resource quantification bank allow the model to be applied to any residential building type.

Finally, the model is applied to a real case study, the rehabilitation of the “Barriada RENFE” building, located in the Macarena District of the city of Seville, Spain.

3.1. Economic assessment: rehabilitation cost database

The aim of this work is to make the comparison between the rehabilitation of a building with serious pathological damage, and its demolition and rebuilding. This comparison is performed in terms of the economic and environmental impact (Alba-Rodríguez, 2016).

In order to obtain the economic evaluation, this study follows the systematic classification of the Andalusia Construction Cost Database (ACCD): a consolidated classification model that is mandatory for public project budgets in Andalusia. Its system for management and classification of work units is flexible and adaptable, thereby enabling

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