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Health & Safety criteria for determining the sustainable value of construction projects

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ABSTRACT

The construction sector ranks among those with the highest accident rates. The incorporation of Health and Safety (H&S) concepts in a construction project has the potential to minimize accident rates and to reduce project costs. However, these concepts must be fully incorporated throughout the building lifecycle: design, construction, useful life, and reintegration. Attention should be paid to the initial design phase, because of its greater impact on accident reduction.

In response to this reality, a mathematical model has been developed for decision-taking purposes using multi-criteria analysis. It is hierarchically structured in accordance with the four lifecycle phases of a building (design, construction, useful life, and reintegration).

The present research is of relevance to ensure that H&S matters are effectively and properly integrated into management projects, through the use of a methodology at the design stage that grades sustainability from low to high on a rising scale of 0–1.

The Health and Safety Costs Index (H&SC Index) is presented as a second index, based on economic criteria, that quantifies the first index in economic terms. Both indices are empirically related by an exponential function. The model is validated through its application to two alternative construction design projects for industrial premises.

1. Introduction

The construction industry represents a substantial portion of the European economy; research and development in this area can have a considerable economic impact. Construction activities in the EU-27 provided employment to an estimated 15 million people in 2010 (some 11.5% of the workforce in the non-financial business economy), while generating an estimated EUR 562 billion of value added: 9.3% of total value added of the non-financial business economy.

However, against the backdrop of the present global economic crisis, migratory movements and birth rates will continue to fall in the EU, as will the need for additional housing units. So, the time has come to reflect on how to optimize future infrastructure and buildings: it is time to promote sustainable development and to incorporate questions relating to economic and social issues (Pons and Aguado, 2012).

Aspects of the construction industry, which are concerned with productivity and worker motivation (Doloi, 2007), complicate optimization of the constructive process, especially in terms of Health and Safety (H&S) issues. Other authors (Rozenfeld et al., 2010) have also highlighted this question through the concept of "Job Safety Analysis" (JSA), which originated in the manufacturing industry and was then exported to the construction industry under the title of "Construction Job Safety Analysis" (CJSA).

In line with these facts that serve to motivate H&S, workplace accidents remain a big human, social and economic problem (Cheng et al., 2012). The construction sector has one of the highest accident rates in comparison with all other industries at an international level (Eurostat, 2009). These are attributable to a great number of factors; the most significant, for the majority of experts (Haslam et al., 2005), are as follows:

- The inherent characteristics of activities that entail a great deal of mobility and changes in on-site conditions from the start up until the end of the construction work.
- Inadequate professional training.
- High levels of subcontracting in the sector.
- The absence of a risk prevention culture.

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- The low importance attributed to H&S in some regions compared with the importance attributed to other aspects such as costs, and quality (Gambatese et al., 1997).

Despite intense legislative activity over recent years (especially in the construction sector), results have fallen short of expectations. Alternative lines of research must therefore be opened, for the development of new methodologies and tools, applicable to the sector, which will reduce accident rates and improve the quality of working life.

With this objective in mind, a methodology is presented in this article that considers the identification and analysis of design, management and execution measures for construction projects throughout their life-cycle (Wadel, 2009). These measures are presented as a hierarchical structure and constitute a solid model for evaluating H&S requirements.

The assessment methodology used in this research, is The Integrated Value Model for Sustainability Assessment or MIVES [*Modelo integrado de valor para evaluaciones de sosteniblidad*]. The MIVES methodology has been developed over the past 10 years by a group of researchers from different Spanish universities and institutes (UPC, UPV/EHU, UDC and TECNALIA). Based on value analysis (Miles, 1961), MIVES transforms different types of variables into one single unit (value function), taking account of the relative importance of various aspects in a project assessment by means of Analytic Hierarchy Process (AHP, developed by Thomas L. Saaty in 1971). MIVES methodology is very useful, therefore, for comparing alternative project designs and choosing those that contribute more than others to sustainable development. This method has been successfully applied to different fields of sustainability evaluation (MIVES I, 2002; MIVES II, 2005; MIVES III, 2009 and MIVES IV, 2010), a good example of which is the sustainable design of concrete structures that was presented, in 2008, in the Spanish Structural Concrete Code [*Instrucción de Hormigón Estructural*] by Aguado et al. (2012) and Del Caño et al. (2012). The latter study made use of the probabilistic approach.

A suitable requirements tree without an excessive amount of indicators is of great importance to arrive at an accurate assessment. To that end, the most significant discriminatory indicators for this sample were selected in collaboration with experts drawn from the construction sector. They were invited to form a "Panel of Experts" that would act as a forum for debate and development, bringing together professionals and researchers with relevant experience and knowledge of the H&S challenges described in this article. The Panel of Experts functioned, to a degree, as a vital connection with the construction sector, for the purposes of this study. It was formed of professionals and researchers of recognized prestige in the fields of safety, health, the environment, and construction management (design, development, and execution), bringing together engineers and architects with expert knowledge of construction and building.

A relatively less well known, but nevertheless practical, decision-making mathematical tool is used, based on Multi-Criteria Decision-Making theory (MCDM) (Pohekar and Ramachandran, 2004). Furthermore, Analytic Hierarchy Process (Saaty, 2008) has been built into the model, which performs a quantitative calculation of a global sustainability index for a building project throughout its life-cycle. This workplace H&S sustainability index, referred to as the "H&S Index", predicts the highest and the lowest accident rates that a construction project might experience throughout the various phases of its life-cycle: construction, useful life, reintegration and demolition.

For the construction sector, the concept of sustainable development is considered the foundation upon which future business initiatives should be built. As a key sector from an economic standpoint, the construction sector should therefore lead these transformations (Hill and Bowen, 1997) in all areas that are considered critical (Fig. 1).

In its early days, sustainable development was related to environmental aspects. Currently, sustainable development requires the simultaneous development of four interrelated dimensions (Pons and Aguado, 2012; Teriö and Kähkönen, 2011; Abeysundara and Babel, 2010): economic, social, environmental and technological. Some of these dimensions will have qualitative and others will have quantitative aspects with different units (Cuadrado et al., 2012). An evaluation is therefore necessary that will allow us to determine whether one activity will achieve higher, lower or similar levels of sustainability in comparison to others.

On the other hand, sustainable development is evidently a very recent discipline and all the more so within the construction sector. In other words, sufficient research is not yet available to establish rigorous, global evaluation models (quantitative) of integral sustainability (economic, social, environmental and technological), but there is a clear tendency to include social aspects as a fundamental pillar of sustainable development (Littig and Griessler, 2005). The majority of tools for the evaluation of sustainability are subject to environmental categories (EcoProfile, GBA), and few of them evaluate categories connected to economics (BES), management (GBC) and transport (BREEAM). However, none of them either evaluate or integrate the H&S category with the other categories in a single tool.

Nonetheless, it is true that there are organizations that have established simplified joint models (in the area of buildings), which normally imply a qualitative global evaluation, although they use both qualitative and quantitative criteria. This is the case of the North American Green Building Council that has created the "Leadership in Energy and Environmental Design System": LEED (US Green Building Council). LEED takes such aspects into account as the construction site, efficient use of water, use of renewable energies and recycled materials, etc. This evaluation system awards points in accordance with the sustainability contribution of each aspect, which represents the scores that are associated with particular categories in the LEED certification scheme.

Moreover, although it is not applicable at all for H&S criteria, the majority of evaluation models in use are also based on weighted scoring systems for different criteria or parameters (Cuchí et al., 2003; ASCE, 2004; San-José and Garrucho, 2010; among others). There is some research underway into the use of other more sophisticated techniques, such as through the hierarchical analytic process or diffuse mathematics and logic,

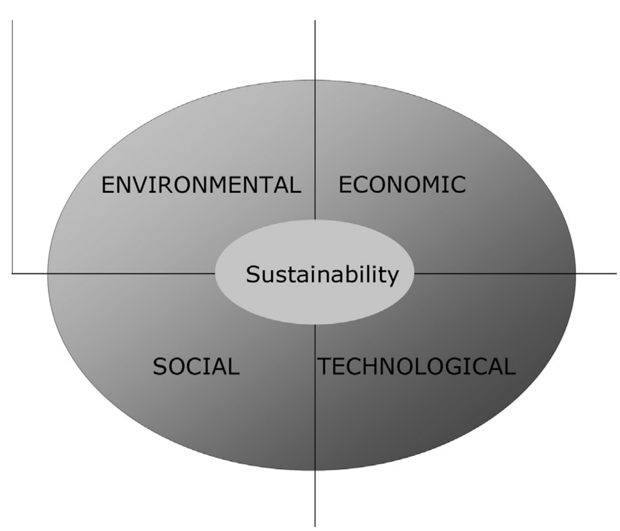

Fig. 1. Evaluation scope of the sustainability study applied to industrial buildings.