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Appraisal of infrastructure sustainability by graduate students using an active-learning method

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ABSTRACT

Currently many university programs in the construction field do not take sustainability into account from a holistic viewpoint. This may cause a lack of sensitivity from future professionals concerning sustainability. Academics in construction must endeavor to instill a culture of sustainability in the curricula of their students. Therefore, this study proposes an active-learning method that allows graduate students in the construction field to take into consideration infrastructure sustainability from a variety of perspectives in a participatory process. The students applied an analytical hierarchical process to determine the appraisal degree of each criterion. A cluster statistical analysis was carried out, aiming to identify the profiles that influence decision-making. This method was applied to two classes of graduate students enrolled in the Master of Planning and Management in Civil Engineering at the Universitat Politècnica de València. This method identified a correlation between the profiles toward sustainability and the characteristics of the chosen infrastructure. It was also found that the method fulfills educational purposes: most of the students obtained more than 65% of the target learning outcomes. This approach promotes awareness and sensitivity to different points of view of the sustainability in a participatory context. It can be replicated in other contexts so as to obtain appraisals regarding various criteria that help enhance decision-making.

1. Introduction

The approach to sustainability has shifted the perspective of modern societies. Sustainability is associated with all practices that lead society to persist, survive and succeed in terms of environmental resources, economic development and quality of life to promote human development (Pappas et al., 2011). Phenomena such as global warming and social pressures, among others, are significant challenges that this generation must confront. Human activities are primarily responsible for these issues. Current development does not respond to existing needs without jeopardizing future generations' welfare. This is the core of the "sustainable development" paradigm (WCED, 1987).

Universities have a key role to play in creating a sustainable future. They educate professionals who are going to shape and manage the future society in the short term (Wright and Wilton, 2012). In the last decade, there has been growing interest in integrating sustainability into university curricula (Boks and Diehl, 2006; Wemmenhove and de Groot, 2001). Its introduction has been undertaken by adding content to existing courses, one-off workshops, or new courses that supplement current programs (Lozano and Young, 2013). Nonetheless, sustainability is a recent idea in modern society, which has not adequately permeated all university strata yet (Lozano, 2010; Lozano and Young, 2013).

Sustainability is composed of three equally important elements: social, economic and environmental (Labuschagne et al., 2005). However, according to Summers et al. (2004), only one-third of the public understands sustainability that way; the other two-thirds take into account only two out of the three aspects, always recognizing the centrality of the environmental component (García-Segura et al., 2014; Torres-Machí et al., 2014). In this line of thought, there are studies (Wright and Wilton, 2012; Watson et al., 2013) that affirm that sustainability is considered in higher education only when focused on the environment. While European experts in sustainability emphasize the sociological role of

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sustainability, most students focus on technology as a solution for environmental issues (Segalas et al., 2010). Additionally, Whitmer et al. (2010) emphasize a lack of successful learning models among the issues of sustainable education.

Aiming to overcome this challenge, Sipos et al. (2008) propose a transformative process that educates people in order to change their frames of reference and worldviews. In this regard, critical thinking processes are vital to boosting learning, rebuilding knowledge and producing new behaviors oriented toward sustainability (Sipos et al., 2008). The Higher Education Academy of the United Kingdom (HEA, 2006) also emphasizes the importance of social, environmental and economic integration, confrontation with real-life complexity, the promotion of critical judgment, professional and personal self-reflection and sustainability assessment. Specifically, some studies (Lozano, 2010; Lozano and Peattie, 2009) have examined the level of awareness in a student's decisions and actions that affect the environment and society. Kagawa (2007) claims that in some instances students are unfamiliar with sustainability, even though they consider it something positive. On the other hand, Byrne et al. (2013) indicate that engineering professionals associate certain concepts with sustainability according to the education they received.

Therefore, several studies (Segalas et al., 2010; Summers et al., 2004; Wright and Wilton, 2012) have identified students' understanding of sustainability. In comparison, other studies put forward the need for reflective analysis to create, correct or improve ways of thinking about sustainability and acting in accordance with its principles (Byrne et al., 2013; Lozano, 2010; Sipos et al., 2008). Some contributors (Sipos et al., 2008; Steinemann, 2003; Whitmer et al., 2010) point out the need to provide new active-learning methods that value judgments on the concept of integral sustainability: learning strategies focused on the student, the development of motivational and practical experiences, or participatory techniques, among others. Bucciarelli et al. (2000) propose project-based techniques to make students learn engineering design. Du et al. (2013) remark on the advantages of problem-based learning that consider the proposals for potential solutions from students. El-Adaway et al. (2015) introduce a hybrid method that combines different techniques, the results of which show that student performance and sense of responsibility increase. Unfortunately, learning strategies focused on infrastructure sustainability are scarce; among the few, Sieffert et al. (2014) propose a set of learning workshops through the design and construction of buildings using waste materials.

Regarding the design and construction of infrastructure, multiple criteria have to be considered in decision-making (Jato-Espino et al., 2014; Arroyo et al., 2015; Torres-Machí et al., 2015). In some cases, these include partial assessment of infrastructure sustainability (Kucukvar et al., 2014; Reyes et al., 2014). However, when these decisions affect sustainability, other opinions have to be considered, because different stakeholders can perceive sustainability according to different degrees of importance (Valdés-Vasquez and Klotz, 2013).

Therefore, there is still room for improvement regarding active-learning methods that value multiple criteria regarding sustainability, particularly those focused on construction. From this point of departure, this study proposes an active-learning method for graduate students to appraise infrastructure sustainability from every facet, considering the multiple preferences of stakeholders and their effect on decision-making. This method is applied to two classes of students enrolled in the Master of Planning and Management in Civil Engineering at the Universitat Politècnica de València (Spain). This paper is organized as follows. First, it presents the proposal. The next section details the selected reference criteria of sustainability. Then, the practical implementation of the prioritization process and the sensitivity analysis are explained. Finally, the formative process is evaluated, the results are discussed and the conclusions are highlighted.

2. Methods

The proposed method is based on active-learning. This approach provides for supporting knowledge conceptualization, development in uncertain contexts and collaborative work by the students (Bucciarelli et al., 2000; Prince, 2004; Sieffert et al., 2014). Furthermore, active-learning presents interesting features such as practical implementation in real-life scenarios, critical thinking and participatory action research, which are key elements in learning about sustainability (Du et al., 2013). These reasons motivate the use of an active-learning method in this research. This method was designed according to the layout shown in Fig. 1 which establishes the stages for project prioritization. This method is linked to the education process applied to two classes of graduate students in the construction field. The educational purpose of this method seeks to achieve learning outputs in terms of four aspects: (1) the appropriate interpretation of the integral sustainability criteria and the identification of indicators for case studies; (2) the application of a method that enables the evaluation of sustainability; (3) the identification of project characteristics that affect sustainability; and (4) the understanding of how preferences regarding sustainability (awareness, value judgment of interest and knowledge) influence the final decision-making process.

This method is based on the issue of prioritization of infrastructure projects regarding their contribution to sustainability; this prioritization is going to be assessed by students. Prior to the participatory process, criteria selection and the evaluation method must be referenced. The criteria are sustainability operating principles that can be identified as a result of the scientific, technical and legislative documentation review. They can also be identified by the experts and stakeholders involved during the infrastructure life-cycle (Kumar and Katoch, 2014). These criteria facilitate the correct understanding of the sustainability concept.

The prioritization of the project alternatives for the chosen criteria is developed using a multi-criteria decision-making tool (Jato-Espino et al., 2014), the purpose of which is to provide a

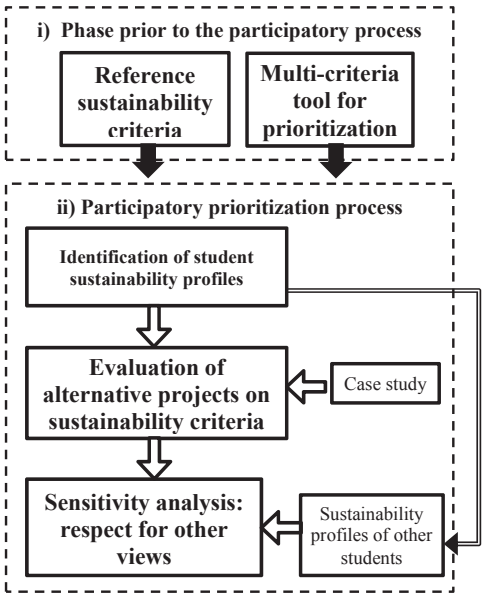

Fig. 1. Development outline of the method.

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