# PERCEPTION OF CIVIL ENGINEERING STUDENTS ABOUT KEY CRITERIA TO ASSESS SUSTAINABILITY

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## Abstract

The construction industry has a severe impact on the environment and social well-being. Recent studies highlight construction industry as a key sector to address the sustainability and numerous engineering programs have been introducing sustainability into their academic curricula and syllabi. This article aims to assess the opinion of civil engineering students about the criteria which influence in the sustainable performance of construction projects. A questionnaire survey was defined to ask students enrolled in undergraduate and graduate degrees about the importance of a range of criteria to assess the sustainability. A total of 355 questionnaires were answered by students at the Universitat Politècnica de València. Statistical analysis was carried out to identify significant differences between students according to their gender, age, nationality and intended area in civil engineering. The results of this research inform about the perception of civil engineering students about the sustainability and the key factors to achieve it.

Keywords: perception of sustainability, statistical analysis, key criteria, civil engineering.

## 1 INTRODUCTION

According to the World Economic Forum [1], the global demand for infrastructure investment is estimated at about US$ 3.7 trillion annually. Construction industry is the sector where majority of people is employed [2] and it possesses a great influence on the regional and national development [3]. Furthermore, civil and construction works are responsible for 60% of raw material consumption [4]. Besides, this sector consumes large amount of energy and is responsible for a high percentage of global emissions [5]. Thus, sustainability is a key factor to be addressed in the construction industry.

Civil engineering programs have been introducing sustainability into their academic curricula and syllabi [6]. This has been partly boosted by Accreditation Board for Engineering and Technology (ABET); since, one of the requirements of the ABET accreditation process is that undergraduate students acquire the skills and knowledge necessary to design systems, components or process taking into account economic, environmental and social constrains [7]. Previous studies have been focused on analyzing the improvement of the sustainability integration in university curricula [8-15], assessing ways of teaching and promoting sustainable development [16-21], new techniques to assess students' knowledge [22-24] or sustainable design skills [22, 25]. However, little is known about the perception of civil engineering students about what criteria are considered the most important to assess the sustainability [6].

This study aims to examine the opinion of students of the Civil Engineering School at the Universitat Politècnica de València (Spain) about what criteria are the most important for achieving a sustainable construction project, and how the students' opinion vary depending on aspects such as gender, age, nationality, intended area in civil engineering.

## 2 MATERIALS AN METHODS

A questionnaire was defined by the authors to collect students' opinion regarding the factors that influence the sustainability of a construction project. This study was applied to students of the School of Civil Engineering at the Universitat Politècnica de València. This school offers 2 bachelor's degree (Bachelor's Degree in Civil Engineering and Bachelor's Degree in Public Works Engineering) and 6 Master's degree (Master's Degree in Civil Engineering, Master's Degree in Planning and Management in Civil Engineering, Master's Degree in Transportation, Land and Urban Development, Master's Degree in Environmental Engineering, Master's Degree in Hydraulic Engineering and Environment, Master's Degree in Concrete Engineering). 355 students were surveyed from September to December 2017.

The questionnaire consisted of three parts. The first part asked about general information of respondents. In the second part, respondents gave information about the preferred area of specialization. Finally, the third part asked students to rank the importance of a set of 28 variables on the sustainability of a construction project by means of a five-level Likert scale: (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, (5) strongly agree. The reliability of the collected responses from the respondents was evaluated with the Cronbach's alpha analysis. Ranging from 0 to 1, the value of Cronbach's alpha of > 0,70 represents good internal consistency or reliability of a sample [26].

Data collected were analyzed using IBM SPSS Statistics software (version 23). First, a statistical characterization of the sample was performed. Then, the statistical significance was analyzed in order to compare groups depending on gender, nationality, degree in which they are enrolled and preferred area in civil engineering. To examine whether the importance of variables vary significantly within these groups, the Mann-Whitney U-test and the Kruskal- Wallis H-Test were conducted. Both tests are non-parametric statistical procedure. The Mann-Whitney U-test is used for comparing two samples that are independent or not related, and the Kruskal-Wallis H-test can be used to compare more than two populations [27].

# 3 RESULTS

## 3.1 Statistical characterization

The 28% of the students of the School of Civil Engineering answered the survey, being 355 the number of surveys that were successfully fulfilled and considered in the analysis. The sample consisted of students of 23 nationalities (74% from Europe, 25% from South America, 1% from Asia and 1% from Africa). 33.8% of the sample was female and 66.2% of the sample was male. 45% of the sample was enrolled in a bachelor's degree and 52% was in a master's degree (Fig.1).

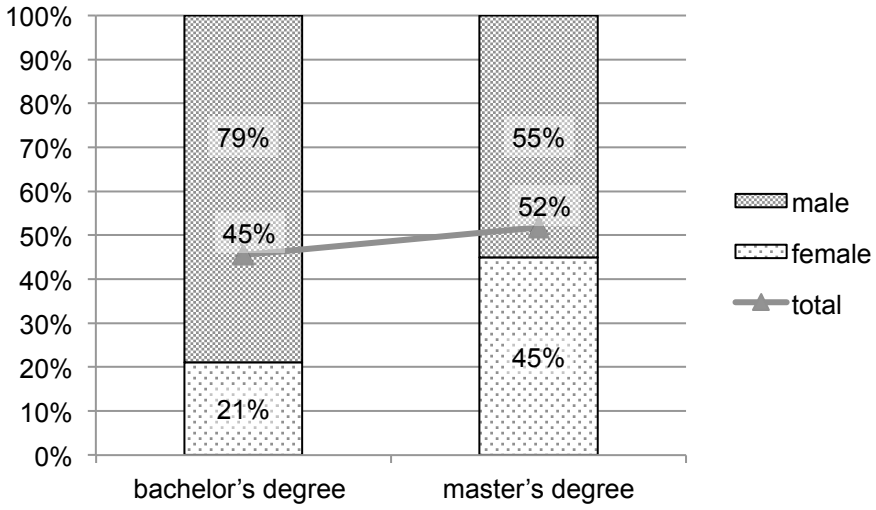


*Figure 1. Percentage of male and female per type of degree*

As it can be seen in Fig. 2, the surveyed students were mainly from Europe. However, there was a wide percentage of students from South America in master's degrees (42.8%). Only the 1.8% and 1.2% in bachelor's degree were from African and Asian countries, respectively. The Fig. 3 shows the preferred area of specialization for the surveyed students. Hydraulic engineering has the highest percentage (28.5%), followed by construction management (23.9%), structural design (19.4%), transportation (14.6%) and environmental engineering (13.5%).

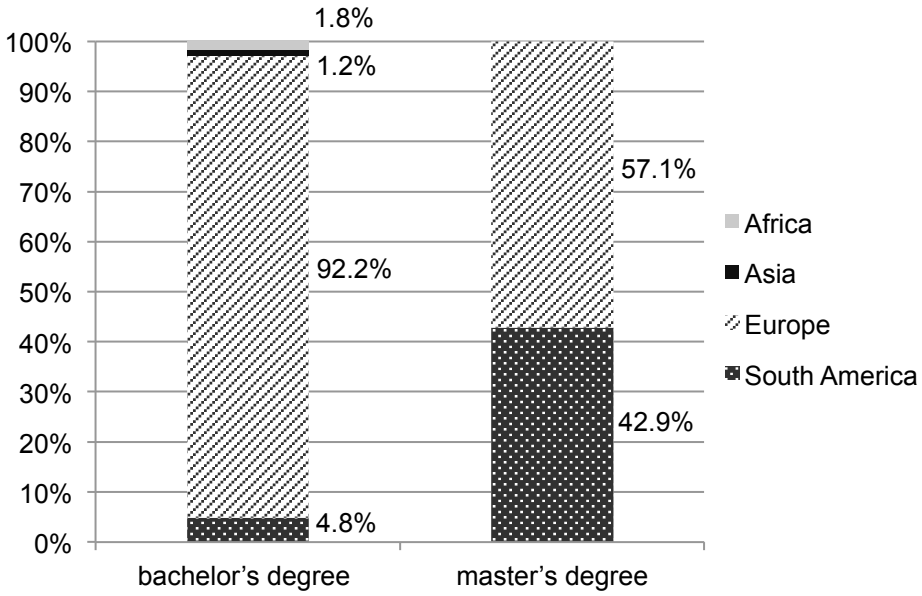


*Figure 2. Origin of surveyed students per type of degree*

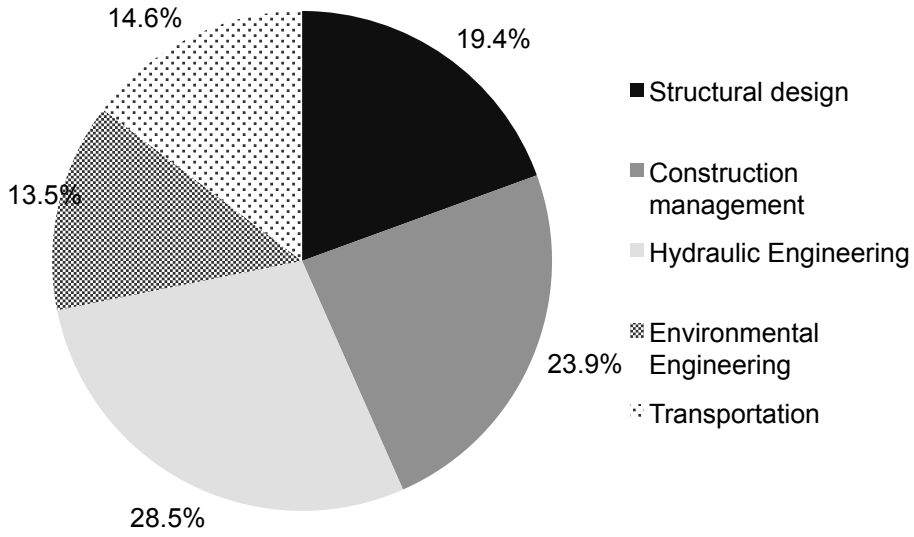


*Figure 3. Preferred areas of specialization selected by the students*

The analysis of the questionnaire survey revealed that the value of Cronbach's alpha is 0.851 which confirms that the sample is consistent and reliable. The results associated with the importance of the variables are given in Table 1. This table shows the considered variables that can influence the level of sustainability of a construction project, the code associated with each variable and a basic statistical description (mean and standard deviation) of the gathered answers. Mean values range from 2.97 to 4.18 and standard deviations range from 0.81 to 1.34. It is interesting to note that project management, resource consumption optimization and health and safety were ranked as the most important variables that can affect the sustainability of a construction project with a mean score of 4.18, 4.08 and 4.02, respectively. Contrarily, gender equality and cultural heritage protection are those with the lowest relative importance; mean score of 3.05 and 2.97, respectively.

***Table 1.*** *Statistical description of each variable*

| Code | Variable | Mean | S.D. |
|---|---|---|---|
| V 01 | Project management | 4.18 | 0.83 |
| V 02 | Resources consumption optimization | 4.08 | 0.81 |
| V 03 | Health and safety | 4.02 | 0.98 |
| V 04 | Reduction of pollution | 3.99 | 0.96 |
| V 05 | Waste management | 3.95 | 1.00 |
| V 06 | Re-use and recycling of materials | 3.95 | 1.01 |
| V 07 | Quality of water resources | 3.94 | 0.85 |
| V 08 | Energy consumption optimization | 3.90 | 0.97 |
| V 09 | Maintenance plan | 3.87 | 0.93 |
| V 10 | Reduction of effects on fauna | 3.79 | 0.97 |
| V 11 | Use of an environmental certification system | 3.73 | 0.96 |
| V 12 | Workforce training | 3.72 | 0.99 |
| V 13 | Air quality control | 3.71 | 1.01 |
| V 14 | Company's experience | 3.70 | 0.98 |
| V 15 | Reduction of effects on vegetation | 3.70 | 1.01 |
| V 16 | Experience of company's workers | 3.66 | 1.00 |
| V 17 | Reduction of effects on users | 3.54 | 0.98 |
| V 18 | Project location | 3.52 | 1.03 |
| V 19 | Cost growth | 3.50 | 1.09 |
| V 20 | Schedule growth | 3.39 | 1.09 |
| V 21 | Noise and vibration control | 3.34 | 0.94 |
| V 22 | Employment creation | 3.33 | 1.05 |
| V 23 | Company's characteristics | 3.33 | 0.99 |
| V 24 | Materials transport optimization | 3.29 | 0.91 |
| V 25 | Type of delivery system | 3.24 | 1.04 |
| V 26 | Local industry participation | 3.21 | 0.98 |
| V 27 | Gender equality | 3.05 | 1.34 |
| V 28 | Cultural heritage protection | 2.97 | 1.09 |

## 3.2 Statistical significance

The relative importance of these variables was analysed according to the type of degree, gender, origin of students and preferred area of specialization. Tables 2, 3, 4 and 5 show the results of these analyses. The Mann-Whitney U-test was used to compare the importance of variables depending on type of degree (bachelor or master), gender and origin of students (Tables 2, 3, 4). Regarding origin of students, only students from Europe and South America were considered because the samples for students from Asia and Africa were too small. The Kruskal-Wallis H-test allows comparing more than two populations, and thus this method was used to compare the importance of variables depending on the intended area of civil engineering (Tables 5). These tables show, for each comparison, only the variables that have significant differences. Table 2 shows that students from bachelor's degree give higher level of importance than students form master's degree to the following variables: gender equality, cultural heritage protection, workforce training, and reduction of effects on vegetation, reduction of effects on fauna and cost growth. Being the most important differences related to gender equality and reduction of effects on vegetation. On the other hand, Table 3 shows that the variables energy consumption optimization, resources consumption optimization, health and safety, use of an environmental certification system, noise and vibration control and air quality control have significant

differences depending on the gender; since the surveyed female consider these criteria more important than the surveyed male.

***Table 2.*** *Relative importance of the variables with significant differences depending on the degree*

| Type of degree | V 27 | V 28 | V 12 | V 15 | V 10 | V 19 |
|---|---|---|---|---|---|---|
| Mann-Whitney U-test | .004 | .004 | .001 | .002 | .000 | .013 |
| Bachelor (N=166) | 3.265 | 3.133 | 3.910 | 3.861 | 4.000 | 3.669 |
| Master (N=189) | 2.847 | 2.815 | 3.545 | 3.540 | 3.587 | 3.354 |

***Table 3.*** *Relative importance of the variables with significant differences depending on the gender*

| Gender | V 08 | V 02 | V 03 | V 11 | V 21 | V 13 |
|---|---|---|---|---|---|---|
| Mann-Whitney U-test | .045 | .010 | .047 | .005 | .005 | .043 |
| Female (N=120) | 4.025 | 4.233 | 4.167 | 3.958 | 3.542 | 3.867 |
| Male (N=235) | 3.838 | 4.004 | 3.953 | 3.626 | 3.251 | 3.634 |

Table 4 shows the relative importance of the variables with significant differences depending on the origin of the students. In this analysis, variables such as project management, waste management, gender equality, cultural heritage protection, re-use and recycling of materials, noise and vibration control, maintenance plan, reduction of effects on vegetation and reduction of effects on fauna have presented significant differences depending on the origin of the students. Results highlight that European students consider more important these variables than South American students. Except project management since South American students give a higher level of importance. The greatest difference, between these groups of samples, can be seen in the variable re-use and recycling of materials.

***Table 4.*** *Relative importance of the variables with significant differences depending on the origin of the students*

| Origin of students | V 01 | V 05 | V 27 | V 28 | V 06 | V 21 | V 09 | V 15 | V 10 |
|---|---|---|---|---|---|---|---|---|---|
| Mann-Whitney U-test | .000 | .011 | .010 | .025 | .015 | .038 | .011 | .004 | .009 |
| South America (N=89) | 4.371 | 3.697 | 2.697 | 2.753 | 3.697 | 3.169 | 3.652 | 3.416 | 3.539 |
| Europe (N=261) | 4.096 | 4.023 | 3.134 | 3.034 | 4.038 | 3.418 | 3.935 | 3.789 | 3.866 |

Finally, if the sample is analyzed taking into account the preferred area of specialization selected by the students, the variables reduction of effects on users, health and safety, use of an environmental certification system, noise and vibration control and reduction of effects on fauna have showed significant differences. In general, students that prefer the area of construction management tend to consider more important these variables than the rest of the students. Except noise and vibration control and reduction of effects on fauna that were more important for students who prefer hydraulic engineering.

***Table 5.*** *Relative importance of the variables with significant differences depending on the preferred area of civil engineering*

| Preferred area of civil engineering | V 10 | V 03 | V 11 | V 21 | V 17 |
|---|---|---|---|---|---|
| Kruskal-Wallis H-test | .028 | .028 | .040 | .038 | .046 |
| Structural design(N=69) | 3.522 | 3.341 | 3.772 | 3.583 | 3.404 |
| Construction management (N=85) | 4.217 | 4.035 | 4.139 | 3.875 | 3.673 |
| Hydraulic engineering (N=101) | 3.942 | 3.671 | 3.554 | 3.979 | 3.712 |
| Environmental engineering (N=48) | 3.580 | 3.118 | 3.347 | 3.354 | 3.423 |
| Transportation (N=52) | 3.913 | 3.518 | 3.921 | 3.833 | 3.712 |

## 4 CONCLUSIONS

This paper analyzes the opinion of students of the Civil Engineering School at the Universitat Politècnica de València about what criteria are the most important for achieving a sustainable construction project. A questionnaire survey was completed from September to December 2017 by 355 students enrolled in two bachelor's degrees and six Master's degrees of this School. The statistical analysis of the collected data highlighted that, out of the 28 variables proposed in this study as variables that affect the sustainability of a construction project, only three have been generally remarked as relevant. These are project management, resources consumption optimization and health and safety. However, an statistical analysis was carried out taking into account the different groups within the sample and significant differences were found; the group formed by females considers energy consumption optimization as an important variable; European students also considered important the waste management and the re-use and recycling of materials; and students whose preferred area of specialization was construction management emphasize the importance of variables such as reduction of effects on fauna and the use of environmental certification systems.

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