# Green public procurement in civil infrastructure construction: current performance and main project characteristics

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## Abstract

Green Public Procurement (GPP) is the alternative for public agencies to purchase goods and services with a reduced environmental impact. GPP encourages the integration of environmental criteria in the procurement procedure to achieve goals related to climate change, resource use, and sustainable consumption and production. The inclusion of environmental criteria in public procurement of civil infrastructure has been claimed as an essential step to enhance sustainability in construction. However, there is limited knowledge of how environmental criteria are currently included in public procurement. This study aims to analyze the inclusion of environmental criteria in public works procurement. To that end, three research objectives are established: (1) identify the environmental criteria included in public-works procurement of civil engineering projects; (2) analyze how these criteria are included in the procurement processes; and (3) identify the characteristics of projects main factors driving in the inclusion of these environmental criteria. This study analyzes 343 tendering documents from 11 different countries at the international level. Tendering documents were analyzed using quantitative content analysis, descriptive statistics, non-parametric techniques, and

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logistic regressions. Within the 343 tends analyzed, the study identified 4,500 instances in which environmental indicators were included in the procurement processes. These instances can be classified into nine criteria (emissions, energy, environmental management, flora and fauna preservation, landscaping, materials, noise and vibration, waste, and water) and 22 subcriteria. These criteria were then analyzed considering their inclusion within the procurement process, in general, and in the different stages of the procurement process, in particular: selection criteria, award criteria, and technical specifications and contract performance clauses. The results show that, although more than 90% of the analyzed tenders included environmental criteria, the environmental management criteria is the only one included as selection criteria and award criteria. Environmental criteria tend to be included as technical specifications and contract performance clauses. Their inclusion depends on the type of civil infrastructure, the size of the contract, and the type of construction work. Nevertheless, the project delivery and procurement methods do not influence the inclusion of environmental criteria. This study helps procurement professionals and researchers implement GPP by providing guidance on how incorporate environmental criteria in the procurement process based on the type of infrastructure and characteristics of the project. This action is necessary for governments interested in improving their performance toward the Sustainable Development Goals.

Keywords: GPP; environmental; sustainability; public-works procurement; civil engineering

## 1. Introduction

Building new infrastructure is essential for our economy but also entails environmental impacts and affection to natural resources. Sustainability has become a critical objective in the development of infrastructure. Designing and building new infrastructure and adapting and reusing existing infrastructure must be addressed to ensure sustainability and a global sustainable development (Taneja et al. 2014). In the last decades, governments have promoted environmental behavior through Green Public Procurement (GPP) (Shadrina et al. 2022). GPP aims to ensure that regulations and guidance in environmental terms are taken into account at the time of bidding and definition of construction contracts (Mahmoud and Beheiry 2021; Shadrina et al. 2022). This approach allows the owner to specify sustainability requirements to potential contractors based on sustainable development goals (Mahmoud and Beheiry 2021), which is essential to guarantee the sustainable success of the project (Xia et al. 2014a).

Environmental criteria can be included within the procurement process as selection criteria, award criteria and/or technical specifications and contract performance clauses (TS&CPC) (The European Commission 2016). Selection criteria establish inclusion and exclusion provisions based, generally, on solvency conditions to filter the participants in the bid. Award criteria gather the criteria considered to choose the best bid, and TS&CPC define the requirements established by the procurer to accept the product or service (Montalbán-Domingo et al. 2019). Although the inclusion of environmental criteria in public procurement can be addressed at different stages of the procurement method, authors such as Perlingeiro et al. (2021) highlighted that the complexity of the aspects related to sustainability makes challenging to include environmental sustainability in the bidding process in a comprehensive way. Palmujoki et al. (2010) stated that the inclusion of environmental criteria in the call for proposals had been fostered, but not its inclusion in contract clauses.

This research aims to analyze the inclusion of environmental criteria in public-works procurement of civil engineering projects. The results allow for assessing how the characteristics of the project influence the inclusion of environmental criteria in public procurement, contributing to identifying the existing weaknesses in the current implementation of GPP and encouraging a comprehensive assessment of the environmental dimension at the procurement level.

## 2. Knowledge Gap and Goals of the Research

### GPP in the construction industry

Ruparathna and Hewage (2015) stated that it is important to assess how sustainability is currently implemented in the procurement process to ensure that it is promoted in an effective and comprehensive way. They gathered 21 tendering documents to analyze the performance of sustainable procurement of construction products and services in Canada. These authors identified the main sustainable criteria in the tendering documents and the median number of sustainable procurement clauses per contract. The results highlighted the lack of inclusion of environmental criteria in tender documents, because of the complexity of including these criteria at the time of procurement before starting construction works.

Over the years, other authors have also assessed how environmental criteria are implemented for green procurement in the construction industry. In this regard, Xia et al. (2014a) gathered 49 requests for proposals to analyze the inclusion of environmental criteria in buildings procured under the Design-Build delivery method in the United States. This study explored the inclusion of LEED certification levels as a criterion within the procurement processes, how it was incorporated into the bidding process, and its level of importance. This contribution highlighted that in Design-Build, sustainability was considered as a subfactor of technical specifications.

Testa et al. (2016) analyzed 164 public tenders in Italy to identify green criteria used in public work tenders of the building sector whose scope was building construction, maintenance, or renovation. This research identified six groups of environmental criteria (energy, materials, water, noise, waste, and recycling). It analyzed their inclusion in each phase of the procurement process, highlighting that their inclusion was mainly as award criteria, technical specifications, and contract performance clauses.

Fuentes-Bargues et al. (2017) assessed the use of environmental tendering criteria in the Spanish public construction sector. These authors gathered 100 cases of public tendering documents, identified the main environmental criteria, and analyzed the impact of project type (i.e., civil engineering or buildings), the geographical scope, and the project budget in the implementation of environmental criteria. These authors also highlighted that the analyses of the environmental criteria inclusion within construction works and services has not been given sufficient attention being necessary a deeper analyses to understand the current performance.

**Factors in the GPP implementation**

Most of the analyses about the inclusion of environmental criteria in public-works procurement have been performed in the building sector. Fuentes-Bargues et al. (2017) and Varnäs et al. (2009) analyzed the differences between building and civil engineering projects and highlighted that environmental criteria are more frequently included in civil engineering projects than in building projects. However, Ruparathna and Hewage (2015) emphasized that civil engineering consultants are unclear on sustainable procurement, and Liu et al. (2019) stated that applying environmental criteria to building projects is easier than in civil infrastructure. Civil infrastructure is characterized by complex projects with large budgets and the potential of important disturbances to the environment and communities (Ugwu and Haupt, 2007; Abdel-Raheem and Ramsbottom, 2016). In terms of sustainability, Bocchini et al. (2014) highlighted that more efforts have focused on defining integral approaches to assess sustainability in buildings than in civil engineering projects. At the procurement level, the inclusion of environmental criteria has been analyzed considering civil engineering projects as a group, without taking into account the differences that may exist among the different types of civil infrastructure (Fuentes-Bargues et al. 2017; Liu et al. 2019; Montalbán-Domingo et al. 2021).

Moreover, construction projects include activities to develop new infrastructure and improve existing ones. Numerous authors have highlighted the importance of fostering the inclusion of environmental criteria in each stage of the infrastructure life cycle (design, construction, maintenance, and rehabilitation, demolition) (Fuentes-Bargues et al. 2019; Moretti et al. 2017). In this regard, Montalbán-Domingo et al. (2022) analyzed the role of the construction industry to satisfy the commitment with the Sustainable Development Goals and emphasized the importance of fostering sustainability in all types of construction projects (building new infrastructure and renovation, rehabilitation, and maintenance works). Nevertheless, very few studies have analyzed the differences in implementing environmental sustainability in public procurement of construction and maintenance infrastructures. In this regard, the building sector has been more widely analyzed (Soto et al. 2020; Testa et al. 2016), and more efforts are needed in the civil engineering sector.

To enhance sustainability in public procurement of the construction industry, selecting appropriate procurement and project delivery methods are also significant managerial decisions that impact the sustainable success of the project (Ahmed and El-Sayegh 2021). According to Loosemore and Lim (2018), integrated delivery methods ensure effective use of resources by encouraging the interaction and synergies between the agents in procurement and allow to increase the capabilities to address the difficulties of the construction industry (Timm et al. 2021). In this regard, Molenaar et al. (2010), Xia et al. (2014), Yu et al. (2020) or Zhong et al. (2022) highlighted that integrated delivery methods provide the opportunity of delivering high-performance sustainable construction projects. Additionally, the use of best-value procurement, instead of lowest-price, allows procurers to communicate their sustainability requirements to potential contractors and include these requirements in the contractor selection process as award criteria (Varnäs et al. 2009; Xia et al. 2014a). Montalbán-Domingo et al. (2019) assessed the role of the project delivery method and the procurement procedure in implementing social criteria in public-works procurement.

However, the influence of these variables in the implementation of environmental criteria is still in its infancy and more efforts are needed to assess their role in including environmental criteria in public procurement (Ahmed and El-Sayegh 2021). Therefore, this study aims to analyze how environmental criteria are included in public procurement. To that end, the study has three research goals: (1) to identify the main environmental criteria in public procurement of civil engineering projects; (2) to analyze how the environmental criteria are included within the procurement process; and (3) to identify how project characteristics influence the inclusion of environmental criteria in each stage of the procurement process.

The paper is structured as follows. Section 3 defines the research method used to achieve the goals of the study. Section 4 shows the results, and Section 5 discusses the results according to the literature review. Finally, conclusions are presented in Section 6, discerning the contributions, implications for theory and practice, limitations, and future research.

## 3. Research method

This research analyzes how environmental criteria are included in public procurement at the international level. The method focuses on analyzing tendering documents at the international level by a content analysis. Once the data is gathered, this is analyzed statistically using descriptive, non-parametric and logistic regression techniques in order to fulfill the three goals of this research. Fig. 1 summarizes the overall research method which is explained in-depth in the following paragraphs. This method was based on Montalbán-Domingo et al. (2018).

The first step involved identifying the variables and environmental criteria to perform the content analysis. These variables were established based on a literature review where journal articles, reports, procurement guidelines, and books were reviewed. Table 1 gathers the five variables selected to characterize each tendering document and the nine environmental criteria established to make up of the first level of the content analysis.

Following the recommendations of Neuendorf (2002) and Stanford et al. (2016), a protocol was created in order to establish the coding procedure, the variables of interest, recommendations about research terms and examples of results. The complete protocol (Protocol S1) is included as Supplementary Material. Based on the protocol, the authors collected tendering documents from eleven English and Spanish-speaking countries from January 2016 to January 2019. These documents were available free online on public procurement internet websites. Only tendering documents that contained the characteristics of the tender, technical specifications and the clauses of the contract were selected.

Once the tendering documents were collected, the content analysis was performed according to the protocol. A quantitative content analysis combining both deductive and inductive approaches was performed (Montalbán-Domingo et al. 2018). The content analysis comprised two steps. The first step consisted in extracting from the tendering documents information about project characteristics, project delivery, procurement procedure and environmental indicators contained in the documents. Based on a deductive approach, this information was classified according to the variables in Table 1. In this process, two coders analyzed the documents and inter-rated reliability was calculated to assess the objectivity of the process and guarantee the proper performance of this type of analysis. Following the recommendations of Cohen (1960) and Stanford et al. (2016), 40 tendering documents, representing more than 10% of the sample, were randomly selected to measure inter-rater reliability. The variable contract size (continue variable) was assessed through the percentage of agreement between raters (PAo); and the rest of variables (discrete variables) were assessed using the Cohen's kappa (Cohen 1960). Cohen's kappa is calculated according to equation (1).

$$\kappa = (PAo - PAg) / (1-PAg) \qquad (1)$$

PAo is the proportion of agreement observed, and PAg is the proportion of agreement expected by chance. PAo and $\kappa$ range from 0.0 to 1.0, with 1.0 representing perfect agreement. Values equal to or greater than 0.80 are considered satisfactory (Neuendorf, 2002; Stanford et al., 2016). In this research, inter-rater reliability proved satisfactory by achieving values over or equal to 0.8 for every variable [for more detail about these methods, see Montalbán-Domingo et al. (2018)].

Once all the tendering documents were analyzed, the second step consisted in carrying out an inductive process where the subcriteria were defined using the affinity diagram technique (Carnevalli and Miguel 2008; Rosenfeld 2014; Thal et al. 2010). This technique organizes data by affinity through the definition of a tree diagram. In this case, the data had already been grouped in a first level of a hierarchical form, based on the environmental criteria, and the affinity was used to establish a second level of subcriteria to cluster the instances of environmental indicators extracted from the tendering documents (Tague 2005). Subsequently, using descriptive statistics, the authors identified the main environmental criteria and subcriteria included in the tendering documents (Goal 1) and analyzed their inclusion in the different stages of the procurement process (Goal 2). Based on Testa et al. (2016), Fuentes-Bargues et al. (2018) and Montalbán-Domingo et al. (2019), three stages of the procurement procedure were considered: (1) the selection criteria stage, which contains the exclusion grounds, and assesses the suitability of the tenderers to undertake the contract; (2) the award criteria stage, which determines the best bid; and, (3) the technical specifications and contract performance clauses stage, which includes the prerequisites and the conditions to perform the contract.

Finally, non-parametric techniques and logistic regressions were performed to identify the most influential factors in the inclusion of each environmental criteria in procurement of civil engineering projects (Goal 3). To perform these analyses, the variables type of civil infrastructure, contract size, type of construction work, procurement method, and project delivery method were categorized (see Table 2).

First, Mann–Whitney U-test and Kruskal Wallis H-test were performed to assess the influence of the project characteristics in the number of environmental criteria per tender. These are non-parametric tests. The Mann–Whitney U-test analyzes significant differences between two categories and was used for the variables type of construction works, procurement method, and project delivery method. The Kruskal Wallis H-test analyzes significant differences between more than two categories and was used for analyzing the variable type of civil infrastructure. Although contract size has three categories, it was analyzed by the Mann–Whitney U-test per pair of categories to assess the variation with the increase in contract size.

Second, logistic regressions were performed to identify the most significant variables regarding the inclusion of each environmental criteria within the procurement process. The logistic regression is a statistical technique that identifies the variables (predictors) that demonstrate strong relationship with the subject of study (dependent variable) (Aznar et al. 2017). The analyses were performed per each stage of the procurement process (Selection criteria, Award criteria, and Technical specifications and contract performance clauses). Nine logistic regressions were calculated to predict the probability of inclusion of each environmental criterion in the tendering documents. The dependent variable was the environmental criterion, categorized as 0 to represent not inclusion, and 1 to represent inclusion. The independent variables were type of civil infrastructure, contract size, type of construction work, procurement method, and project delivery method. The results of the logistic regression were analyzed based on the coefficients of the independent variables (B), the Wald statistic, and the odds ratio [Exp(B)] (Field 2013). The B coefficients predict the probability of occurrence of a dichotomous dependent variable. The Wald statistic represents the significance of the B values for the logistic regression model. The Exp (B) allows assessing the odds change resulting from a unit change in the predictor. The statistical analyses were developed using IBM SPSS Statistics (23.0).

## 4. Results

### Sample Characterization

The dataset includes 343 tendering documents. The sample gathers tendering documents from eleven countries (Argentina, Australia, Canada, Chile, Colombia, New Zealand, Panama, Peru, Spain, the United Kingdom, and the United States of America); and, considering the budgets of these 343 projects, the sample represents a total contracting capacity above 5 billion euros. Table 3 shows the distribution of the sample based on the project characteristics, categorized in five different types of civil infrastructure (i.e., airport, highway, maritime work, railway, water infrastructures). Forty nine percent of the sample corresponds with tenders whose aim is developing new infrastructure and 51% with tenders to work over existing infrastructure, such as renovation, expansion and maintenance projects. The variable contract size was categorized in three levels: projects with a budget less than one million euros (1M€), between one and 10 million euros (1M€-10M€), and larger than 10 million euros (>10M€). 50% of the sample corresponds to projects whose budget is under 1M€.

According to the dataset, the traditional design-bid-build is more commonly used than the integrated project delivery. Numerous authors have stated that moving to integrated project delivery is the way to enhance construction knowledge, experience, sustainability, and innovation in construction projects (Marinelli and Antoniou 2020). However, procurers tend to abstain from the opportunity to create financial benefits and reduce risks (Ruparathna and Hewage 2015b) because these delivery methods are found to be more costly and less competitive (Naoum and Egbu 2016). However, the results showed that the traditional project delivery was selected in 70% of the contracts to build new infrastructure and in 100% of contracts to maintain or rehabilitate the existing one.

Concerning the procurement process, in general terms, best value (57%) tends to be used more frequently than lowest price (43%). This result is in line with authors such as Okunlola (2012), Montalbán-Domingo et al. (2019) and Calahorra-Jimenez et al. (2020) who claimed that the construction industry is aware of the importance of best value procurement as an opportunity to select the most advantageous proposal considering other factors in addition to price. Its use is becoming more frequent than the lowest price. However, this general trend is not seen in all types of civil infrastructure. Airport and highway projects tend to select the best value more frequently than the lowest price. Contrarily, the lowest price is more common in maritime and railway projects. Moreover, Figure 2 shows the use of each procurement procedure depending on the project delivery method and the construction works (building new infrastructure or work on the existing one. The lowest price is preferred over best value in renovation, expansion, and maintenance projects of existing infrastructure (Fig. 2).

**Main environmental criteria (Goal 1) and their inclusion in the procurement process (Goal 2).**

According to the dataset, the first step focused on identifying the main environmental criteria included in public-works procurement of civil engineering projects (Goal 1). To that end, the study identified 4,500 instances in which environmental indicators were included in the procurement processes. These instances were classified into the nine criteria previously established. Subsequently, the instances were clustered into 22 subcriteria. Table 4 gathers the subcriteria and shows the percentages of tendering documents that considered them (%) and the average of instances of each subcriterion per tender (#). This analysis was performed considering the total of stages of the procurement process (global) and discerning between the three stages that these processes involve (selection criteria, award criteria, and technical specifications and contract performance clauses). Table 4 shows the percentage of consideration of each environmental criterion in the analyzed sample. The nine environmental criteria were included in more than 90% of the analyzed tenders. The environmental criteria were included in 34% of tenders as selection criteria, 21% as award criteria, and 87% as technical specifications and contract performance clauses). The environmental management criterion was included in more than 88% of the tendering documents analyzed, followed by waste, flora and fauna preservation, emissions, noise and vibration, and water (included in more than 50% of the sample). However, energy (14.6%), landscaping (17.2%), and materials (34.7%) were the least considered criteria.

The subcriterion environmental management plan was considered in 85.7% of the tenders analyzed, construction/demolition waste management and disposal was included in 61.2%, and protection of vegetation and restoration of natural vegetation and damaged lands was included in 55.7%. However, subcriteria, such as materials with eco-label (0.3%), energy performance certificate (1.5%), use of renewable energies (2.9%), environmental certifications (8.2%), and water treatment and restoration measures, were included in less than the 10% of the tenders.

Subsequently, the inclusion of the environmental criteria and subcriteria in each stage of the procurement process was analyzed (Goal 2). As can be seen in Table 4, the environmental criteria were usually included as technical specifications and contract performance clauses, despite previous researchers (Palmujoki et al. 2010) have claimed that environmental criteria are not included in construction contract clauses. The environmental management criterion is the only one included as selection criteria (35.9% of tenders) and award criteria (21.3% of tenders). This criterion is, therefore, an opportunity for the contracting agency to require contractors to demonstrate the implementation of environmental management measures and verifications, allowing them to establish standards to control every type of environmental criterion (Kozik and Karasińska-Jaśkowiec 2019). In the selection criteria stage, the environmental management plan (21.9%) and professionals with expertise in environmental management (16.9%) are the two subcriteria more commonly considered. However, in the award criteria phase, only environmental management plans tend to be requested, but at a low frequency (18.4%). In technical specifications and contract performance clauses stage, more than one indicator per subcriterion is usually included per tender to try to cover different environmental aspects of each subcriterion. The criterion that includes more instances per tender is flora and fauna preservation (5.8), followed by noise and vibration (3), waste (3), and water (3.1).

**Influential factors in the inclusion of environmental criteria in public-works procurement of civil engineering projects (Goal 3)**

The third goal aimed to analyze how the project characteristics can influence the inclusion of environmental criteria within the procurement process of civil engineering projects. To that end, first, the study analyzed, through non-parametric techniques, whether the project characteristics influence the number of criteria per tender; second, logistic regressions were performed to identify, in each stage of the procurement process, the influential factors in the inclusion of each environmental criterion.

To boost environmental sustainability in the construction industry, numerous authors have claimed the importance of promoting the inclusion of environmental requirements in public-works procurement. Moreover, this inclusion must be addressed from a comprehensive approach to helping achieve the Sustainable Development Goals targets established by United Nations Member States (Montalbán-Domingo et al. 2020). However, the sample analysis showed that the average number of criteria per tender was 4.35, even though the number of environmental criteria established to be included in public procurement is nine. The U de Mann-Whitney and Kruskal-Wallis tests showed that the number of criteria per tender (dependent variable) varies significantly depending on the contract size and the type of civil infrastructure (p-value for both variables is less than 0.05 in Table 5). In particular, the significant differences in the contract size variable exists between the groups [1 M€-10 M€]

and [> 10 M€] as the p-value was 0.008. However, the groups [< 1 M€] and [1 M€-10 M€] do not show significant differences.

Table 6 shows that the mean frequency of environmental criteria per tender increases with the contract size. For contracts with budgets under or equal to 10M€, highway and airport projects have, on average, more environmental criteria per tender than other project types; however, when the contract size is over 10M€, railway projects include, on average, the highest number of environmental criteria per tender, followed by airports.

On the other hand, non-parametric analyses highlighted that the procurement method, the project delivery system, and the type of construction work do not significantly influence the number of environmental criteria included in the tender (see Table 5). During the last decades, numerous authors have emphasized the importance of moving from traditional delivery methods to integrated ones to foster sustainability in the construction industry (Ruparathna and Hewage, 2015b; Xia et al., 2015; Naoum and Egbu, 2016); however, the data set concluded that integrated methods show slight differences about the average of criteria per tender respect to the traditional methods (integrated: 4.7; traditional: 3.9). This behavior was similar for the procurement procedures. Previous research has claimed the importance of using best-value procurement procedure to improve sustainable performance during the contract execution (Brammer and Walker 2011; Palmujoki et al. 2010); nevertheless, the data set shows that the lowest price includes lightly more environmental criteria per tender than the best value (lowest price: 4.4; best-value: 3.9). This result was similar to Montalbán-Domingo et al. (2019). These authors analyzed the inclusion of social criteria in tendering documents at the international level and found no significant differences in the inclusion of social criteria regarding procurement procedure. In this regard, Varnäs (2008) and Ruparathna and Hewage (2015b) claimed the trend of using the lowest price in civil engineering projects because of the uncertainty associated with the construction works and the difficulty of defining objective criteria. This difficulty seems to be shared with the inclusion of environmental criteria in public-works procurement of civil engineering projects.

Finally, logistic regressions were performed to identify how the project characteristics influence the inclusion of each environmental criterion in each stage of the procurement process. For each logistic regression, the dependent variable was the environmental criterion, categorized as 0 (not inclusion) and 1 (inclusion), and the independent variables (predictors) were the type of civil infrastructure, the contract size, the type of construction work, the procurement method, and the project delivery method. In the selection criteria and award criteria stages, only the criterion of environmental management was analyzed.

Table 7 gathers the results for the selection criteria stage. Only the results associated with those independent variables that were significant ($p$-value<0.05) are included. As can be seen, the logistic regression revealed that the inclusion of environmental management as selection criteria depends on the type of construction work and the procurement method since this criterion tends to be considered more frequently in existing infrastructure works (renovation, expansion and maintenance projects ) and under the lowest price (see table 7).

Regarding the award criteria stage, the inclusion of environmental management as an award criterion in best-value procurement depends significantly on the type of infrastructure, the contract size, and the type of construction work (see table 8). According to the Wald statistics, type of infrastructure (Wald: 14.954) and contract size (Wald: 10.925) are the variables that influence the most the inclusion of environmental management as award criterion. In contract size, the comparison of the categories 1 [1M€-10 M€] and 2 [> 10 M€] with respect to category 0 [< 1 M€] shows that the inclusion of environmental management in contract size between 1 M€ and 10 M€ is 1.938 times higher than contract size under 1M€, and this relation is higher for contracts over 10M€ with respect to those under 1M€ (Exp(B): 3.466).

In terms of type of infrastructure, the inclusion of environmental management as award criterion tends to be included in the public-works procurement of highway, airport, and railway projects; and its inclusion is 2.3 (1/0.433) times higher when the aim of the project is building new infrastructures in comparison with maintaining and rehabilitating them.

To analyze the inclusion of each environmental criterion in the TS&CPC stage, nine logistic regressions were performed. For each logistic regression, the dependent variable was the environmental criterion (0 = not inclusion and 1= inclusion), and the independent variables were project delivery method, procurement method, type of civil infrastructure, contract size, and type of construction work. Table 9 shows only the independent variables that significantly influenced the inclusion of each environmental criterion. Type of civil infrastructure, contract size, and construction work are the most influential variables. According to the Wald statistics, the type of infrastructure is the variable with the greatest influence on emissions, flora and fauna preservation, waste, water, and noise and vibration criteria. Contract size influences significantly in the inclusion of environmental management, landscaping, and water. Finally, the type of construction work only influence the criterion of materials.

Highway, maritime, and airport projects tend to include TS&CPC about emissions more than water and railway projects. The odds ratio is around two times higher. Flora and fauna preservation is 2.5 times more included in highway and airport projects than the rest of the infrastructures. Waste and Water criteria are included similarly in every type of infrastructure. Only railway projects show a lower percentage of inclusion. Regarding the water criterion, its inclusion increases with the contract size. Noise and vibration tend to be comprised mainly in highway projects. Environmental management and landscaping tend to be included as TS&CPC in projects with a contract size over 10M€. Material is the only criterion that depends on the type of the construction work and the type of infrastructure. This criterion tends to be comprised in renovation, expansion, and maintenance projects and, especially, in airport projects. Finally, it is important to highlight that energy was only included in 13.4% of tenders analyzed, and its inclusion does not depend on any of the variables considered.

## 5. Discussion

The results show that 90% of the tenders include some form of environmental protection action. Environmental criteria were included as technical specifications and contract performance clauses in 87% of tenders; however, 34% of tenders included environmental criteria as selection criteria, and 21% as award criteria. These lower values are in line with the ones registered by other studies. For example, Testa et al. (2016) analyzed 164 public work tenders focused on construction, maintenance or renovation of buildings; they found that only 35% of the analyzed tenders included any form of green criteria. Xia et al. (2014b) studied 49 Design Build request for proposals of buildings; they claimed that the 67% of the sample included sustainability requirements as criteria within the procurement procedure. Ruparathna and Hewage (2015) analyzed 21 tendering documents about construction products and services; they showed that only 33% of sample incorporated environmental criteria. Finally, Fuentes-Bargues et al. (2017) investigated 100 projects tendered of buildings and civil infrastructures; they showed that 35% of the sample used environmental criteria when contracting construction projects.

This study has identified nine environmental criteria included in the procurement of civil infrastructure. These criteria can be classified into three groups based on the frequency there are included in the tendering documents. The environmental management criterion forms the first group since it is the only one included in more than 80% of tenders. Authors such as Bohari et al. (2020), Puig et al. (2015), and Humphreys et al. (2003) emphasized that implementing environmental management techniques is essential to work on minimizing environmental degradation and enhancing the environmental performance of an industry.

The second group includes five criteria: emissions, waste, water, flora and fauna preservations, and noise and vibrations. These criteria are included in more than 50% of the tenders (waste: 67.1%; flora and fauna preservation: 57.7%; emissions: 52.2%; noise and vibrations: 52.2%; and, water: 51%). These criteria are essential to defining requirements associated with the construction activities and the infrastructure to be developed (Bohari et al. 2020). Authors such as Fuentes-Bargues et al. (2019) found similar results. Furthermore, Berry and Mccarthy (2011) highlighted in the Construction Industry Research and Information Association (CIRIA)' s guide to sustainable procurement in construction that the main environmental issues are resource depletion and the increasing stress on water, land and air from the way we produce, use and waste resources.

Finally, energy, materials, and landscaping form the third group, which is characterized by the low frequency they are included in the procurement documents (i.e., materials: 34.7%; landscaping: 17.2%; and energy: 14.6%). The use of materials with recycled and reused content and the implementation of measures to guarantee energy efficiency have been claimed mainly in the building subsector; however, in civil infrastructures, these criteria have not grown in importance (Fuentes-Bargues et al. 2019). Landscaping is a criterion mainly considered in the design stage to select the best solution to develop the infrastructure (CEEQUAL 2019; ISI 2015). According to Garbarino et al. (2016), each project is unique and not every criterion must be incorporated into the procurement process.

Therefore, the results show that: (1) although in global terms most of the procurement procedures include some kind of environmental criteria, more efforts are needed to foster their inclusion as award criteria or selection criteria; (2) some environmental criteria, such as energy, materials and landscaping, show a low percentage of inclusion; and (3) the procurement procedure and the project delivery method do not influence significantly in the inclusion of environmental criteria. In this regard, Testa et al. (2016), Ruparathna and Hewage

(2015), and Oltean-Dumbrava and Miah (2016) claimed that there is a lack of knowledge about how to implement environmental criteria within the procurement process. Park et al. (2015) claimed the difficulty of assessing environmental criteria in an objective way to ensure transparency, objectivity, and equitability of bid selection processes.

Consequently, more efforts are needed to guarantee that the environmental criteria are implemented in public-works procurement of civil infrastructures in a comprehensive way. To help with this need, several agencies such as the European Commission, the U.S. Department of Transportation, Australian Government, among others, have developed guides to incorporate green criteria in the procurement process of road design, construction and maintenance (FHWA 2010; Garbarino et al. 2016b), road lighting and traffic signals (European Commission 2018), waste water infrastructure (European Commission 2013), and airport infrastructures (Heathrow 2017; National Academies of Sciences, Engineering 2013).

Nevertheless, there is a lack of guidance about how to include environmental criteria in procurement process of railway, maritime and water infrastructures in general. These facts have been observed in the results of this study, where highway and airports are the infrastructures with more criteria per tender in their procurement process. However, the results have shown that railway and airport construction contracts over 10M€ are the infrastructures with the highest mean of criteria per tender. The reason is that railway and airport construction contracts over 10M€ entail the construction of buildings as railway stations or airport terminals. The implementation of environmental criteria in GPP of buildings has been extended over the last decade (Testa et al. 2016). The most important criteria in GPP of buildings are those related to energy performance or materials (Liu et al. 2019; Testa et al. 2016; Varnäs et al. 2009) and these criteria are the less considered by civil infrastructures. Therefore, joining both types of infrastructures (building and civil engineering) in only one contract entails increasing the number of environmental criteria per tender.

Another result to be highlighted is that the environmental management criterion is usually included as TS&CPC; however, in existing infrastructure works and under the lowest price procurement method, this criterion is often also included as selection criteria. Renovation, rehabilitation, and maintenance works of existing infrastructure tend to be procured in a traditional way (lowest price and traditional project delivery method) (NCHRP 2009). In these scenarios, the inclusion of environmental criteria is lower than in contracts to build new infrastructure (Garbarino et al. 2016b). According to Eckelman et al. (2014), contracts focused on refurbishing or replacing infrastructures tend to center only on cost minimization. Raising awareness about the importance of incorporating environmental criteria in every stage of the infrastructure's life cycle is essential (Trunzo et al. 2019); especially taking into account that 55% of the targets to achieve the Sustainable Development Goals depend directly on the performance of civil engineering projects (Montalbán-Domingo et al. 2022).

On the other hand, the results highlight that in civil engineering projects, there is a lack of awareness of the importance of reducing, managing and controlling energy consumption (Liu et al. 2019). This criterion is rarely included in the procurement of civil engineering projects, even though national action plans for GPP have emphasized the importance of establishing measures to foster efficiency and save energy (Tarantini et al. 2011). Similarly, recycling and reusing material is hardly considered in civil infrastructure. The results of this study show that only maintenance works in airports promote the inclusion of this type of criteria in the procurement processes. Airports are centers of constant development where a high amount of waste is generated due to land excavation, runway maintenance, construction of new terminals, etc. Therefore, during the last decades, airports with high passenger traffic levels have promoted environmental measures to minimize waste generation (Sebastian and Louis 2021). Highway projects show the opposite behavior. Over the last decades, numerous studies have researched using recycled materials to build or maintain this civil infrastructure.

However, there has not been a real application because of the fear of leaching contaminants to underlying soil layers and groundwater aquifers (Azadgoleh et al. 2022).

Finally, numerous authors have highlighted the importance of the best value procurement method and integrated project delivery methods to achieve sustainability comprehensively and effectively (Xia et al. 2014b; Yu et al. 2020; Zhong et al. 2022). However, the results of this research highlight that these variables do not influence the inclusion of environmental criteria in public-works procurement of civil infrastructures. The collaborative relationship and the union between the different stages favor the project's sustainability by carrying out more coordinated actions and considering the stakeholders' opinions in decision-making (Olanipekun et al. 2018).

## 6. Conclusions

### Contributions

Civil infrastructures are essential for the economic development of countries, but their construction can cause damage and destroy natural habitats, negatively impacting biodiversity and affecting the everyday life of the population. To move the construction industry toward sustainable development, Green Public Procurement has been promoted during the last decade; and integrated project delivery methods and best-value procurement methods have been highlighted as crucial elements for achieving sustainable construction. This research aimed to analyze the current performance of the inclusion of environmental criteria in public-works procurement of civil engineering projects and how aspects related to the project delivery, the procurement method, the type of civil infrastructure, the type of construction work, and the contract size influence promoting environmental sustainability through public procurement.

This research analyzes 343 tendering documents to answer the following goals: (G1) identifying the main environmental criteria in public procurement of civil engineering projects;

(G2) analyzing how these criteria are included within the procurement process; and, (G3) identifying the most influential factors in the inclusion of environmental criteria in public-works procurement of civil engineering projects. The research method is based on content analysis, descriptive statistics, non-parametric analyses, and logistic regression techniques.

The findings of related to the first goal of the study (G1) showed that environmental criteria were included in more than 90% of the analyzed tenders. Nine criteria to assess environmental sustainability were identified: emissions, energy, environmental management, flora and fauna preservation, landscaping, materials, noise and vibration, waste, and water. Environmental management is the only criterion included in more than 80% of tenders. Emissions, flora and fauna preservation, noise and vibrations, waste, and water were observed in around 50% of the tenders. Energy, landscaping, and materials had the lowest rates of inclusion. Environmental criteria were usually included as technical specifications and contract performance clauses.

The analyses of the environmental criteria within the procurement procedure (G2) showed that, the inclusion vary depending on the stage. The environmental criteria were included in 34% of tenders as selection criteria, 21% as award criteria, and 87% as technical specifications and contract performance clauses. Additionally, only the environmental management criterion was included as selection criteria and award criteria, but in less than 30% of the tenders.

The identification of the most influential factors in the inclusion of environmental criteria in public-works procurement (G3) was addressed under two perspectives: the number of criteria per tender and the inclusion of each environmental criterion in each stage of the procurement process. The results showed that the average number of environmental criteria per tender was 4.35. The procurement method, the project delivery method, and the type of construction work did not significantly influence the number of criteria per tender. This value only varies significantly depending on the type of infrastructure and the contract size. In contract size under or equal to 10M€, highways and airports show the highest number of criteria per tender; however, when the contract size is over 10M€, globally, the values increase significantly, and airports and railway projects are the two types of infrastructures with the highest number of criteria per tender. The main reason is that these projects usually entail the construction of buildings, such as railway stations or airport terminals, and there is more knowledge and awareness about how to improve the environmental performance of buildings by boosting energy or materials measures, contrarily to civil engineering projects.

Concerning the main factors that influence each stage of the procurement process, the results showed that environmental management tends to be considered as selection criteria more frequently in existing infrastructure works and under the lowest price procurement method. As award criteria in the best value procurement method, this criterion tends to be included in public-works procurement of new highway, airport, and railway projects; its inclusion increases significantly with the contract size. Finally, in the TS&CPC stage, the results showed that the inclusion of emission, flora and fauna preservation, noise and vibration, waste, and water criteria depend mainly on the type of civil infrastructure. Highway and airport projects generally tend to include these criteria more frequently than other infrastructures. Water and railway projects show less awareness about the importance of implementing environmental criteria in public-works procurement. Projects with a contract size over 10M€ tend to focus on assessing environmental performance in terms of environmental management, landscaping, and water; the material criterion is the only one that depends on the type of construction work, being mainly included in works over existing infrastructures and in airport projects.

**Recommendations**

The findings of this research show that there is still a lack of knowledge about implementing environmental criteria in public-works procurement of civil engineering projects. First, there is a need to assess the environmental dimension of sustainability from a comprehensive point of view; most of the environmental criteria are included in low percentages, and only environmental management is globally implemented. Guaranteeing a comprehensive inclusion of every environmental criterion in every type of civil infrastructure is essential to moving the construction industry toward the Sustainable Development Goals. Second, the efforts seem to focus on promoting GPP in large projects to build new civil infrastructure. Procurers must make an effort to implement environmental sustainability in every type of construction work, considering new and existing infrastructure, regardless of the contract size. Third, environmental criteria tend to be included as technical specifications and contract performance clauses and rarely are considered as award criteria in best value procurement process. The inclusion of environmental criteria as award criteria allows the procurer to consider environmental policy objectives in their procurement activities and the construction companies to propose improvements according to their resources, their construction management strategies, and their level of environmental awareness. This represents an opportunity for the construction companies to move from a passive perspective, where the environmental conditions are imposed by the procurer, to an active perspective, where they can see in their environmental strategy the opportunity to gain the contract, achieve their business goals and improve their corporate image.

**Limitations**

The gathered documents were collected from public procurement Internet websites. Although the searches were largely consistent, some tendering documents could have been mischaracterized. Therefore, this study cannot claim a truly random sample. However, these limitations are also shared by other studies based on the content analyses of tendering documents. Additionally, the study analyzes tendering documents from eleven countries. The environmental policies of each country could influence the results.

**Future Research**

Future research is needed to assess the importance of the environmental and social criteria in the procurement method; and how their weights vary depending on aspects such as the contract size, country, and type of infrastructure. Moreover, the variable country should be analyzed in detail to assess the inclusion of environmental criteria in public works procurement depending on the context (country) where the project is built. Finally, an objective method should be defined to establish the level of importance of each environmental criterion based on the environmental performance of each country and the project characteristics.

**Data Availability Statement**

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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**Supplemental Materials**

The Protocol S1, defined to perform the content analysis, can be found online in the ASCE Library (www.ascelibrary.org)

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## LIST OF FIGURES

**Table 1.** Variables to characterize each project and environmental criteria

| **Project characteristics** | **Source** |
|---|---|
| Type of civil infrastructure: airport, highway, maritime works, railways, and water | Garbarino et al. (2016a); Thacker et al.(2019); Moretti et al. (2017) |
| Contract size: Initial budget (€) | Lines and Miao (2016); Stanford et al. (2016); Xia et al. (2013) |
| Type of construction work: new infrastructure and existing infrastructure (maintenance and rehabilitations works) | Moretti et al. (2017); Taneja et al. (2014) |
| Procurement method: Lowest price and best value | Molenaar et al. (2010); Stanford et al. (2016); Xia et al. (2013) |
| Project delivery method: Traditional (DBB) and Integrated (DB, CMR, Concessions, PPP, etc.) | Gransberg and Barton (2007); Naoum and Egbu (2016); Pellicer et al. (2016); Xia et al. (2013) |
| **Environmental criteria** | **Source** |
| Emissions | Dasgupta and Tam (2005); Fernández-Sánchez (2012); FHWA (2012); ISI (2015); Muench et al. (2011); Rodríguez-López and Fernández-Sánchez (2011) |
| Energy | ISI (2015); Rodríguez-López and Fernández-Sánchez (2011); Shen et al. (2011) |
| Environmental Management | Garbarino et al. (2016a);Tam et al. (2004) |
| Flora and Fauna | Faith-Ell et al. (2006); Fuentes-Bargues et al. (2017); ISI (2015); NYSDOT (2009) |
| Landscaping | Fernández-Sánchez (2012);Sarkis et al. (2012) |
| Materials | Petkovic et al. (2004);Casanovas-Rubio and Ramos, (2017); Liu et al. (2019) |
| Noise and Vibration | Shen et al. (2007); Garbarino et al. (2016a) |
| Waste | Cook et al. (2017); Fernández-Sánchez (2012); Rodríguez-López and Fernández-Sánchez (2011) |
| Water | Dobrovolskiien and TamošiIuniene (2016); Ugwu et al. (2006); Ugwu and Haupt (2007) |

**Table 2.** Categories of the independent variables

| Independent variables | Categories |
|---|---|
| Type of civil infrastructure | 0: Highway; 1: Maritime works; 2: Water; 3: Airports; 4: Railways |
| Contract size | 0: < 1 M€; 1: 1 M€-10 M€ ; 2: > 10 M€ |
| Type of construction work | 0: New infrastructure; 1: Existing infrastructure |
| Procurement method | 0: Lowest price; 1: Best value |
| Project delivery method | 0: Traditional; 1: Integrated |

**Table 3.** Summary of the data sample

| Type of civil infrastructure | Total (#) | Type of construction work | | contract size | | | Project delivery | | Procurement process | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | New infra. | Existing infra. | <1M€ | 1M€ - 10M € | >10 M€ | Traditional | Integrated | Lowest price | Best value |
| Airport | 18 | 44% | 56% | 39% | 28% | 33% | 67% | 33% | 33% | 67% |
| Highway | 180 | 39% | 61% | 47% | 32% | 21% | 89% | 11% | 36% | 64% |
| Maritime work | 42 | 50% | 50% | 62% | 26% | 12% | 86% | 14% | 55% | 45% |
| Railway | 28 | 36% | 64% | 32% | 57% | 11% | 82% | 18% | 54% | 46% |
| Water | 75 | 77% | 23% | 59% | 33% | 8% | 81% | 19% | 49% | 51% |
| Total | 343 | 49% | 51% | 50% | 34% | 17% | 85% | 15% | 43% | 57% |

**Table 4.** Environmental criteria and subcriteria

| Criteria | Subcriteria | Global | | SC | | AC | | TS&CPC | |
|---|---|---|---|---|---|---|---|---|---|
| | | % | # | % | # | % | # | % | # |
| **Emissions** | Reducing and controlling the emissions of polluting gases | 35.6 | 1.8 | - | - | 1.5 | 1 | 34.7 | 1.8 |
| | Minimizing the emissions of dust and other particles | 47.2 | 2.7 | - | - | - | - | 47.2 | 2.7 |
| | **Total** | **52.2** | **3.7** | **-** | **-** | **-** | **-** | **51.6** | **3.7** |
| **Energy** | Minimization and control of energy consumption | 14 | 1.2 | - | - | 1.5 | 1 | 12.8 | 1.2 |
| | Use of renewable energies | 2.9 | 1.1 | - | - | - | - | 2.9 | 1.1 |
| | Energy Performance Certificate | 1.5 | 1 | - | - | - | - | 1.5 | 1 |
| | **Total** | **14.6** | **1.5** | **-** | **-** | **1.5** | **1** | **13.4** | **1.5** |
| **Environmental Management** | Environmental Management Plan | 85.7 | 1.4 | 21.9 | 1 | 18.4 | 1 | 75.8 | 1 |
| | Environmental certifications | 8.2 | 1 | 5.5 | 1 | - | - | 2.6 | 1 |
| | Professional expertise in Environmental Management | 34.1 | 1.2 | 16.9 | 1 | 2.9 | 1 | 19.2 | 1 |
| | **Total** | **88.6** | **1.9** | **35.9** | **1.2** | **21.3** | **1** | **76.4** | **1.3** |
| **Flora and Fauna Preservation** | Protection of vegetation and restoration of natural vegetation and damaged lands | 55.7 | 3.4 | - | - | 0.9 | 1.7 | 55.1 | 3.4 |
| | Protection and control of fauna species | 38.5 | 3.2 | - | - | - | - | 38.5 | 3.2 |
| | Erosion and Sedimentation Plan | 24.8 | 1 | - | - | - | - | 24.8 | 1 |
| | **Total** | **57.7** | **5.8** | **-** | **-** | **0.9** | **1.7** | **57.1** | **5.8** |
| **Landscaping** | **Total** | **17.2** | **1.5** | **-** | **-** | **0.6** | **1** | **15.7** | **1.6** |
| **Materials** | Recycling or reuse | 34.7 | 1.6 | - | - | 4.4 | 1 | 32.1 | 1.6 |
| | Eco-label | 0.3 | 1 | - | - | 0.3 | 1 | 0 | - |
| | **Total** | **34.7** | **1.6** | **-** | **-** | **4.4** | **1.1** | **32.1** | **1.6** |
| **Noise and Vibration** | Minimizing noise and vibrations | 51.6 | 2.5 | - | - | 1.7 | 1 | 51.3 | 2.5 |
| | Construction Noise and Vibration Control and Management Plan | 22.2 | 1.1 | - | - | - | - | 22.2 | 1.1 |
| | **Total** | **52.2** | **3** | **-** | **-** | **1.7** | **1** | **51.9** | **3** |
| **Waste** | Construction/demolition waste management and disposal | 61.2 | 2.1 | - | - | 3.2 | 1 | 60.6 | 2.1 |
| | Reduction of pollution caused by the spillage | 35.9 | 1.2 | - | - | 0.6 | 1 | 35.3 | 1.2 |
| | Minimizing waste generation | 18.7 | 1.4 | - | - | 0.6 | 1 | 18.1 | 1.4 |
| | **Total** | **67.1** | **3** | **-** | **-** | **3.8** | **1.2** | **66.2** | **3** |
| **Water** | Water quality protection and control | 48.4 | 2.8 | 0.3 | 1 | 0.3 | 1 | 48.1 | 2.8 |
| | Treatment and restoration measures | 9.3 | 1 | - | - | - | - | 9.3 | 1 |
| | Minimizing water consumption | 14.9 | 1.1 | - | - | - | - | 14.9 | 1.1 |
| | **Total** | **51.0** | **3.1** | **0.3** | **1** | **0.3** | **1** | **51** | **3.1** |

Note: SC= Selection criteria; AC= Award criteria; TS&CPC=Technical specifications and contract performance clauses; % = percentage of tenders; # = average of instances per tender. Global: considering all stages of the procurement process

**Table 5.** Significant variables in the number of criteria per tender

| Variable | | Statistical Parameter | gl | Sig. |
|---|---|---|---|---|
| Project delivery system | | 6233.000* | 1 | 0.051 |
| Procurement method | | 13328.500* | 1 | 0.243 |
| Type of construction work | | 14110.000* | 1 | 0.517 |
| Contract size | 0 - 1 | 9621.500* | 1 | 0.821 |
| | 1 - 2 | 2514.000* | 1 | **0.008** |
| Type of civil infrastructure | | 13.197** | 4 | **0.010** |

Note. *: U de Mann-Whitney; **: Kruskal-Wallis; Sig. = 2-tailed p-value (significant if <0.05). Contract size (0: < 1 M€; 1: 1 M€-10 M€ ; 2: > 10 M€);

**Table 6. Criteria** per tender depending on the contract size and the type of infrastructure

| Contract size | Civil engineering infra. | Sample | Min. | Max. | Mean | Standard Deviation |
|---|---|---|---|---|---|---|
| **≤10M€** | Highway | 142 | 0.00 | 9.00 | 4.65 | 2.36 |
| | Maritime works | 37 | 1.00 | 7.00 | 3.92 | 2.13 |
| | Water | 69 | 0.00 | 9.00 | 3.61 | 2.62 |
| | Airport | 12 | 1.00 | 8.00 | 4.33 | 2.50 |
| | Railway | 25 | 0.00 | 8.00 | 3.04 | 2.84 |
| | Total | 285 | 0.00 | 9.00 | 4.15 | 2.50 |
| **>10M€** | Highway | 38 | 1.00 | 9.00 | 5.11 | 2.82 |
| | Maritime works | 5 | 1.00 | 8.00 | 5.20 | 2.68 |
| | Water | 6 | 0.00 | 8.00 | 5.17 | 2.93 |
| | Airport | 6 | 5.00 | 8.00 | 6.50 | 1.64 |
| | Railway | 3 | 7.00 | 7.00 | 7.00 | 0.00 |
| | Total | 58 | 0.00 | 9.00 | 5.36 | 2.64 |

**Table 7.** Results of logistic regression. Dependent variable: Environmental management in the selection criteria stage

| Independent variables | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| Construction work | .594 | .278 | 4.579 | 1 | .032 | 1.812 |
| Procurement method | .520 | .252 | 4.260 | 1 | .039 | 1.682 |
| Constant | -.958 | .333 | 8.262 | 1 | .004 | .384 |

Note: B: Regression coefficients (in log-odds units); S.E.: square errors; Wald: Wald statistic; df: degrees of freedom; Sig.: 2-tailed p-value (significant if < 0.05); Exp(B): log-odds of success. Construction work (0: new infrastructure; 1:existing infrastructure); Procurement method (0: lowest price; 1: best value).

**Table 8.** Results of logistic regression. Dependent variable: Environmental management in award criteria stage

| Independent variables | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| Construction work | -.837 | .321 | 6.799 | 1 | **.009** | 0.433 |
| Contract size | | | **10.925** | 2 | **.004** | |
| Contract size: 1-0 | .661 | .326 | 4.124 | 1 | .042 | 1.938 |
| Contract size: 2-0 | 1.243 | .387 | 10.331 | 1 | .001 | 3.466 |
| Type of infrastructure | | | **14.954** | 4 | **.005** | |
| Type of infrastructure: 1-0 | -2.042 | .758 | 7.261 | 1 | .007 | 0.130 |
| Type of infrastructure: 2-0 | -1.000 | .393 | 6.472 | 1 | .011 | 0.368 |
| Type of infrastructure: 3-0 | -1.292 | .796 | 2.635 | 1 | **.105** | 0.275 |
| Type of infrastructure: 4-0 | -.860 | .579 | 2.209 | 1 | **.137** | 0.423 |
| Constant | -.851 | .322 | 6.976 | 1 | .008 | 0.427 |

Note: B: Regression coefficients (in log-odds units); S.E.: square errors; Wald: Wald statistic; df: degrees of freedom; Sig.: 2-tailed p-value (significant if < 0.05); Exp(B): log-odds of success. Construction work (0: new infrastructure; 1: existing infrastructure); Contract size (0: < 1 M€; 1: 1 M€-10 M€ ; 2: > 10 M€); Type of infrastructure (0: highway;1:maritime works; 2:water;3:airports;4:railways).

**Table 9.** Results of logistic regression with each environmental criterion as dependent variables in TS&CPC stage

| Dependent variable | Independent variables | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| Emissions | Type of infra. | | | 14.398 | 4 | .006 | |
| | Type of infra.: 1-0 | -.587 | .376 | 2.430 | 1 | .119 | .556 |
| | Type of infra.: 2-0 | -.844 | .316 | 7.125 | 1 | .008 | .430 |
| | Type of infra.: 3-0 | -.612 | .529 | 1.339 | 1 | .247 | .542 |
| | Type of infra.: 4-0 | -1.411 | .455 | 9.601 | 1 | .002 | .244 |
| Energy | - | - | - | - | - | - | - |
| Environmental Management | Contract size | | | 6.562 | 2 | .038 | |
| | Contract size: 1-0 | -.531 | .307 | 2.998 | 1 | .083 | .588 |
| | Contract size: 2-0 | -.898 | .373 | 5.804 | 1 | .016 | .407 |
| Flora and fauna preservation | Type of infra. | | | 13.810 | 4 | .008 | |
| | Type of infra.: 1-0 | -.987 | .371 | 7.077 | 1 | .008 | .373 |
| | Type of infra.: 2-0 | -.708 | .306 | 5.344 | 1 | .021 | .493 |
| | Type of infra.: 3-0 | .486 | .601 | .655 | 1 | .418 | 1.626 |
| | Type of infra.: 4-0 | -.934 | .426 | 4.798 | 1 | .028 | .393 |
| Landscaping | Contract size | | | 6.562 | 2 | .038 | |
| | Contract size: 1-0 | -.531 | .307 | 2.998 | 1 | .083 | .588 |
| | Contract size: 2-0 | -.898 | .373 | 5.804 | 1 | .016 | 0.407 |
| Materials | Construction work | 1.500 | .337 | 19.862 | 1 | .000 | 4.482 |
| | Type of infra. | | | 19.534 | 4 | .001 | |
| | Type of infra.: 1-0 | -.531 | .440 | 1.459 | 1 | .227 | .588 |
| | Type of infra.: 2-0 | .295 | .347 | .723 | 1 | .395 | 1.343 |
| | Type of infra.: 3-0 | 1.779 | .617 | 8.323 | 1 | .004 | 5.927 |
| | Type of infra.: 4-0 | -2.927 | 1.043 | 7.883 | 1 | .005 | .054 |
| Noise and Vibration | Type of infra. | | | 14.401 | 4 | .006 | |
| | Type of infra.: 1-0 | -.747 | .369 | 4.099 | 1 | .043 | .474 |
| | Type of infra.: 2-0 | -.766 | .307 | 6.251 | 1 | .012 | .465 |
| | Type of infra.: 3-0 | -1.093 | .525 | 4.334 | 1 | .037 | .335 |
| | Type of infra.: 4-0 | -1.166 | .438 | 7.093 | 1 | .008 | .312 |
| Waste | Type of infra. | | | 12.335 | 4 | .015 | |
| | Type of infra.: 1-0 | -.329 | .395 | .692 | 1 | .405 | .720 |
| | Type of infra.: 2-0 | -.584 | .322 | 3.290 | 1 | .070 | .558 |
| | Type of infra.: 3-0 | .317 | .608 | .272 | 1 | .602 | 1.373 |
| | Type of infra.: 4-0 | -1.401 | .441 | 10.107 | 1 | .001 | .246 |
| Water | Contract size | | | 6.718 | 2 | .035 | |
| | Contract size: 1-0 | .086 | .254 | .114 | 1 | .735 | 1.090 |
| | Contract size: 2-0 | .894 | .350 | 6.521 | 1 | .011 | 2.446 |
| | Type of infra. | | | 10.316 | 4 | .035 | |
| | Type of infra.: 1-0 | .119 | .368 | .105 | 1 | .746 | 1.126 |
| | Type of infra.: 2-0 | -.568 | .309 | 3.377 | 1 | .066 | .567 |
| | Type of infra.: 3-0 | .613 | .570 | 1.155 | 1 | .282 | 1.846 |
| | Type of infra.: 4-0 | -1.018 | .449 | 5.138 | 1 | .023 | .361 |

Note: B: Regression coefficients (in log-odds units); S.E.: square errors; Wald: Wald statistic; df: degrees of freedom; Sig.: 2-tailed p-value (significant if < 0.05); Exp(B): log-odds of success. Construction work (0: new infrastructure; 1: existing infrastructure); Contract size (0: < 1 M€; 1: 1 M€-10 M€; 2: > 10 M€); Type of infrastructure (0: highway; 1: maritime works; 2: water; 3: airports; 4: railways).