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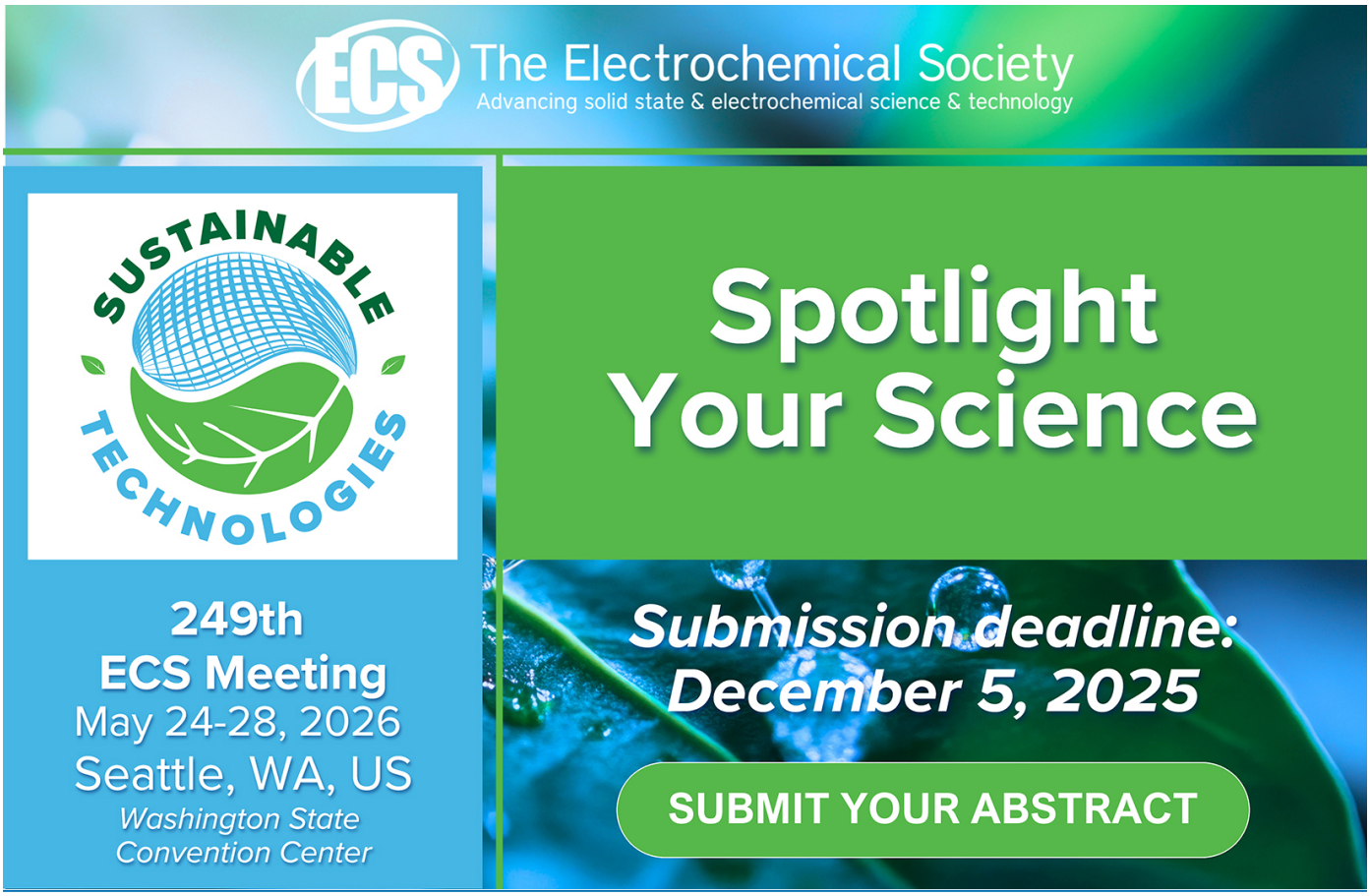
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Computer sciences applied to the sustainability of projects

T Velásquez-Pérez[1], **H F Castro-Silva**[2], **and L F Quijano-Brand**[2]
[1] Grupo de Investigación en Tecnología y Desarrollo en Ingeniería (GITYD), Universidad Francisco de Paula Santander, Seccional Ocaña, Colombia
[2] Universidad Pedagógica y Tecnológica de Colombia, Sogamoso, Colombia

E-mail: tvelasquezp@ufpso.edu.co

Abstract. Computer science incorporates information theory that is a fundamental element in project management. Achieving the conservation of the current resources for future generations has become an increasingly important and urgent challenge for our society. Thus, the sustainability topic becomes more valid on the agenda of governments and organizations. This cross-section empirical study presents partial results of the perception of a representative sample of engineering project managers in Colombia about the implementation of sustainability elements in the management of these projects, established in the sustainable project management maturity model. The results applying information science, indicate a greater orientation towards the aspects of product sustainability than the project process and in general that in the studied context, the economic dimension significantly predominates over social and environmental aspects.

1. Introduction

The realization of this study arises from the need to integrate the sustainability and project management (PM) topics, as well as the growing importance of both issues in the global context of organizations and society in general. This study objectives are aimed at answering the research question: how are sustainability aspects arranged in the SPM3 model, integrated in the engineering PM in Colombia, based on the project managers' perception? and to contribute to fill a gap identified in the integration of sustainability and PM topics in the scientific literature. This document is structured in three sections, the first one is devoted to present a general context of sustainability and PM topics, the second describes the methodology used to achieve the objectives and finally the findings of the study are concluded.

The current reality of society and the concern to deliver a better world to future generations pose important challenges in the environmental, social, and economic fields [1], generating a global positioning of the topics related to sustainability. One of the most widely accepted concepts of sustainable development integrates the economic, environmental, and social dimensions and is known as the triple-bottom-line (TBL) [2]. Although for [3] sustainability deals with four perspectives (environmental, economic, ethical, and sustainable governance); this study embraces the generally accepted model of [4] based on the TBL sustainability defined by John Elkington in 1994 [5].

The use of computer science has had significant growth since the '90s in social research [6] and the economic sciences [7,8]. Contributions have been highlighted in Latin America [4]. However, it is still under-employed [9]. The grave problems facing today's society and the efforts to meet current needs without compromising resources for future societies have led to growing interest in the topic of sustainable development [10]**.** The projects as fundamental elements of development and the growing

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interest in the implementation of the PM methodologies and standards play a fundamental role in the fulfillment of the purposes of sustainable development [10,11].

On the other hand, project management has evolved as a discipline of wide expansion and acceptance in the organizational environment as a fundamental element to achieve business objectives [12]. Projects are crucial for sustainable development, the integration of these two topics has gained recent interest in PM academics and practitioners generating a current that considers sustainability as a project objective and as a characteristic of the PM processes [13]. The generally accepted PM methodologies are issued by important professional associations of the discipline. Among the most globally recognized PM organizations are the Project Management Institute (PMI), The Association for Project Management (APM) and the Francophone Association for Project Management (AFITEP), which have achieved great acceptance of their bodies of knowledge such as the PMBOK and APMBOK [14]. However, these standards hardly consider techniques and tools to plan a project from the perspective of sustainability [15]. Nevertheless, the integration of sustainability in the project management field and the design of associated strategies, techniques and tools to be implemented in the PM, is an important and current challenge for the discipline.

According to the above, this cross-section empirical study presents partial results of the perception of a representative sample of engineering project managers in Colombia about the implementation of sustainability elements in the management of these projects, established in the sustainable project management maturity model.

2. Methodology

The objectives of this study are to present how the three sustainability dimensions are taken into account in the engineering project management in Colombia by using the SPM3 maturity model and to determine the existence of significant differences in the implementation of aspects related to the economic, environmental and social dimensions of the SPM3 model. In this order of ideas, the research development is framed in the non-experimental quantitative paradigm, because it uses data collection and statistical analysis to check hypotheses, establish patterns and test theories [16]. Likewise, for this study we analyzed the variables derived from the proposed specific objectives in search of an approach to the facts linked and related to the context of the management of Colombian engineering projects. This study is exploratory, descriptive and cross-sectional [17] because it includes the registration and interpretation of the way in which the sustainability purposes are intended to be achieved in the engineering project management in Colombia, for which a series of key variables that can describe such process are defined [16]. This indicates that, through the study of the variables, the researcher can understand the fact on which the research was set and oriented. Likewise, the research is causal considering that it is intended to determine the influence of certain independent variables on another dependent, in this case, the implementation of sustainability tools in the engineering project management [18]. In order that the results of this research can be compared with those obtained in other studies, the methodology design is like that of studies with common characteristics in other areas such as those of [19,20]. Consequently, once the literature review was made, it was decided to evaluate the perception of the project management sustainability based on the standard SPM3 questionnaire supplied in [21], adapting it in a section to the Likert scale of measurement and adding a section to inquire demographic information of the project director participating in the study and the area of engineering to which the projects he/she directs belong. The population of this research is constituted by the total number of engineering project directors in Colombia and therefore of large size, considering also that the parameter to be estimated is a proportion and that prior studies are not considered, therefore, it is required to use a random sampling [22]. The determination of the size of the representative sample was made based on the recommendations of [23], for a scenario of maximum variability, that is with $p = q = 0.5$, with a significance level of 5%, a maximum estimation error of 0.10 (e), we obtained that the sample size is 67 engineering project directors. Electronic means were used to send and receive the questionnaires, in total 480 were sent and only 70 were correctly received for a response rate of 14.58%, consistent with that obtained in this type of studies [24]. The tabulation and analysis of the data, both descriptive and

hypothesis tests, was carried out in the statistical software R®. The analysis of the collected data is shown in the following section, mainly focusing on the implementation of the sustainability aspects of projects framed within the SPM3 model.

3. Results

This section presents the demographic characteristics of the sample and the results of the study are discussed with a view to responding to the research question. The sample consists of 70 engineering project directors, 62% of them have certification in some PM standard; 42% have more than 15 years of experience as a project manager, 28% have experience between 10 and 15 years, 20% have between 5 and 10 years of experience and the remaining 10% have less than 5 years of experience. In relation to the areas of engineering, 38% of the participants in the study work in construction projects for civil works, 28% in projects of mechanical construction and assembly, 15% direct projects related to electrical and electronic engineering and the remaining 9% direct comprehensive engineering projects. To answer the question of how sustainability elements are implemented in engineering projects in Colombia, the PM sustainability maturity model SPM3, is taken as a reference. The project managers selected in each of the sustainability indicators the level that most accurately describes the management of their projects, both from the perspective of the project process and the project product; the results of the economic dimension of sustainability in the PM are illustrated in Table 1. As shown in Table 1, the indicators of the economic dimension of sustainability in the PM are the highest within the general elements of the SPM3 model, which indicates the project orientation towards the generation of value in the organizations, the highest indicators for the project process and the product correspond to the investment profitability and the competitive potential.

For the environmental and social dimensions of sustainability, the indicators are only located at level 1 of maturity, corresponding to the compliance with rules and regulations, and in some cases indicators of labor practices and decent work, and responsibility with society and the client are located at level 2 of maturity or reactive. In general, the results of this research show that, in Colombia, the engineering project management sustainability is located only at the lowest level of maturity, giving rise to opportunities for improvement related to the integration of sustainability in the strategic planning of the organizations, aligning with the global tendencies of concern for the environment and society, in order to get the management of this type of projects to a level of proactive maturity of the PM from early stages of the life cycle of the projects until their closure. When comparing the results of the process sustainability indicators with those of the process product, the results of this research show the orientation towards the aspects related to the engineering project deliverables. The project managers who participated in the study also evaluated each of the PM sustainability indicators according to their project performance with a Likert scale. The results were grouped according to the correspondence of the indicators to the three dimensions of sustainability to obtain the average assessment, obtaining an average score for the indicators of each of the three dimensions of sustainability in project management 2.33-3 in “project process” point “economic sustainability”, 1-1.22 in “project process” point “environmental sustainability” and 1.43 in “project process” point “social sustainability”. These average values confirm the orientation of PM sustainability towards the economic dimension, leaving aside the aspects related to the protection of the environment and society.

The orientation towards the economic dimension in project management holds for both the project management processes and the project product. These results are consistent with the findings of Castro-Silva *et al.* [25]. By comparing the means in the three dimensions of sustainability in project management these means were subjected to a variance analysis (ANOVA) in the R® software in order to test the null hypothesis of equality of means H_0: $\mu_1 = \mu_2 = \mu_3$, the ANOVA results for $Pr < F$ or the observed p-value that is compared with the significance level of 0.05 (5%) and measures the probability of committing the type I error, yields a value of 0.001 that is less than the significance level ($0.0001 < 0.05$) so the null hypothesis of equality of means can be "rejected". The Bonferroni *post hoc* test indicates that there is a significant difference in the mean of the indicators associated with the economic dimension with the mean of the other two dimensions and that there is no significant difference among the means

of the indicators of the social dimension with respect to the environmental dimension. These results allow us to conclude that in the opinion of the project managers, the economic dimension of sustainability is what directs the engineering project management in Colombia.

Table 1. Sustainability maturity level.

		Integration of sustainability in the project			
		Level 1 Compliance	Level 2 Reactive	Level 3 Proactive	Level 4 Purpose
Economic sustainability	Return on investment	X	X	X	
		X	X	X	X
	Business agility	X	X		
		X	X	X	
	Competitive potential	X			
		X	X	X	X
	Business continuity	X	X		
		X	X		
	Motivation and incentives	X			
		X			
	Risk reduction	X			
		X	X		
Legend of the cells		Project process in dark color Project product in light color			

4. Conclusions

The results of this empirical and cross-sectional study allow to conclude that according to the perception of a sample of engineering project managers in Colombia, the management of this type of interventions is only at the lowest level of sustainability of the SPM3 model, demonstrating that the organizations of these projects are mainly oriented to comply with the rules and regulations on social and environmental topics related to the context and execution of their projects. This finding allows PM academics and practitioners to direct their efforts to propose PM strategies and tools aimed at improving the environmental and social indicators of sustainability. On the other hand, the results indicate that the organizations that develop engineering projects are more oriented to the sustainability of the engineering project deliverables or products than towards the sustainability of the process management of these projects. When comparing the process management with the process product management, the assessments of the project product management were especially greater in the sustainability indicators in the environmental dimension in transport and materials and resources, and in the social dimension, the indicators of labor practices, social responsibility and corporate governance. Finally, it is verified that there is a significant difference of the assessments granted by the engineering project directors to the indicators of each one of the sustainability dimensions, being greater in the economic one than in the environmental and the social ones. It should be noted that it is necessary to be prudent when generalizing the results of this research, taking into account limiting factors such as that it is based on the participants' perception, that it is a snapshot associated with the particular moment to apply the information collection instrument, and the sample size.

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