Guide for prioritization of project management processes (PMBoK) in vertical construction projects

Guía para la priorización de procesos de gestión de proyectos (PMBoK) en proyectos de construcción vertical

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Resumen

Introducción: La utilización de buenas prácticas para la gestión de proyectos de construcción vertical se constituye en un tema de vital importancia en pro de que su planeación, ejecución y resultados sean acordes con los criterios de éxito deseados a nivel productivo, reducción de costos, anticipación de inconvenientes, entre otros. Por lo tanto, es pertinente estudiar la forma como se gestionan los proyectos de construcción teniendo en cuenta la implementación de metodologías o guías que favorezcan la buena gestión de los proyectos.
Objetivo: Proponer una guía para la priorización de procesos de gestión de proyectos propuestos por el Project Management Institute aplicada especialmente a proyectos de construcción vertical.
Metodología: Se elaboró un diagnóstico de la situación actual mediante revisión de la literatura y la recolección de lecciones aprendidas de expertos mediante encuesta; seguidamente, la guía fue formulada y estructurada y finalmente, validada mediante el juicio de expertos y el análisis de polaridad de textos.
Resultados: Se obtuvo un proceso para diseñar la guía que puede ser extrapolado a otros contextos, la guía propuesta y un detallado proceso de validación, que permitió obtener percepciones positivas respecto a su uso y utilidad. Adicionalmente, se elaboró un instrumento para apoyar la priorización de procesos de gerencia de proyectos el cual se encuentra publicado.
Conclusiones: La guía metodológica propuesta permite priorizar la gestión de los procesos de las áreas de conocimiento y fue evaluada con buenas opiniones. El proceso seguido provee una guía para hacer la adaptación de procesos de gerencia de proyectos en otros contextos y áreas de aplicación.

Palabras clave

Proyectos; Gestión de proyectos; Proyectos de construcción; Proyectos de construcción de edificios; Guía de priorización. PMI; Project Management Institute; PMBoK.

Abstract

Introduction: The use of good practices for the management of vertical construction projects constitutes an issue of vital importance in order that its planning, execution, and results are in accordance with the desired success criteria at a productive level, cost reduction, anticipation drawbacks, among others. Therefore, it is pertinent to study the way construction projects are managed, considering the implementation of methodologies or guides that favor good project management.
Objective: This article proposes a tool that extracts information from repositories hosted on GitHub. It analyzes the data using computational techniques and presents the results through visualizations that identify the field's technological evolution studied through the most used programming languages, central repositories, and organizations.
Method: A diagnosis of the current situation was made through a review of the literature and the collection of lessons learned from experts through a survey; Subsequently, the guide was formulated and structured, and finally, validated through expert judgment and analysis of text polarity.
Results: Obtaining a process to design the guide that can be extrapolated to other contexts, the proposed guide, and a detailed validation process, which allowed obtaining positive perceptions regarding its use and usefulness. Additionally, an instrument was developed to support the prioritization of project management processes which is published.
Conclusions: The proposed methodological guide allows prioritizing the management of the processes of the knowledge areas and was evaluated with good opinions. The process followed provides a guide for adapting project management processes in other contexts and application areas.

Key Words

Projects, Project Management; Project building; Construction building project; Guide of priorization; PMI; Project Management Institute; PMBoK.

I. INTRODUCTION

Nowadays, project management has become an axis of support for several organizations [1]; therefore, it becomes crucial that the projects undertaken have a good performance. The 2015 Standish CHAOS Group report [2], highlights that the success of projects is given by meeting deadlines, budget and a satisfactory outcome for the company or client that develops or finances it. In 2018, it is found that 9.9% of every dollar invested in projects is wasted due to poor project performance, taking this value to a global scale means that, of the total capital investment in the world, approximately $1 million is lost every 20 seconds, or $2 trillion every year [3]. Additionally, according to Pulse of the Profession 2023 [4], it mentions that among the drivers of project success are high project management maturity, good stakeholder management, quality involvement and risk management, among others, hence the importance of good project management.

The Pulse of the Profession 2021 [5], presents improvements in project performance despite the pandemic caused by COVID-19, as follows:

- The percentage of projects completed within scope was 73% in 2021, compared to 69% and 68% in 2020 and 2019.
- The percentage of projects completed within the original budget was 62% compared to 59% and 57% in 2020 and 2019.
- The percentage of projects completed on time was 55% compared to 53% and 51% in 2020 and 2019;
- There was also a decrease in failed projects and lost budget of 12% in contrast to 13% and 15% in 2020 and 2019.

The improvements in performance in general terms have been given by the continuous inclusion of best practices in project management [6, pp. 2–3], the speed that companies had to adapt to digital transformation, business strategies and the use of tools that favor the adoption of these good practices, among others [5].

The construction sector is no stranger to this scenario, since it reported improvements in project performance in 2021 [5], thus: 74% of projects were completed meeting objectives, 60% within budget, 57% on time. Therefore, every day the focus is on improving the performance of projects under construction to avoid wasting money due to their poor performance [3], since construction worldwide has been considered a key companion of civilizations in search of a better quality of life. The construction sector is thus considered transversal to the economy of nations, considering the demand for jobs and the

capital contributions generated for the benefit of a nation. In Colombia, "construction has been one of the most dynamic sectors in recent years and a driver of the national economy" [7], generating approximately 1.5 million direct jobs [8].

According to the Colombian Chamber of Infrastructure [9], construction projects in Colombia are affected by different factors, among which are: insufficient studies and designs, lack of planning in infrastructure, deficiency in preparation of the budgets for the works, delays in complying with requirements in social and environmental management, delays in the acquisition of properties, lack of inter-institutional coordination, differences in the social management of the communities and distortion in the work of the auditing, factors that are mostly directly related to project management. This is where the use of good practices for project management plays a fundamental role in the planning, execution, and closure of these. In such a way, projects under construction require efficiency in efforts for their successful completion in time, with low cost, generating value for their users and clients, involving high levels of quality and reliability in vertical construction.[10]. Therefore, it is pertinent to study the way in which construction projects are managed and there is more and more interest in the implementation of methodologies or guides that favor good project management.

In this order of thought, the Project Management Body of Knowledge -PMBoK [11] provides a set of best practices grouped into knowledge areas and process groups, where each process provides inputs, techniques or tools and outputs that can be adapted according to the needs and context of each project and application area, becoming a base on which organizations can build methodologies, policies, procedures, rules, tools and techniques, life cycle phases necessary for the practice of management of projects[11, p. 2]. Additionally, the Project Management Institute (PMI), in 2003, presented the publication of an extension to the PMBOK® GUIDE specific to the Construction sector [12], which specifically covers construction projects, adding two new areas of knowledge that should be managed in the development of construction projects, with which it makes manifest the differences between this type of projects and those of other sectors.

Regardless of the size of the company or the project, a construction project manager must recognize and promote the application of the processes that make up the 12 knowledge areas proposed by the PMI® [11] and 8 performance domains[13].

Considering the growth before the pandemic and the strategies projected by the Ministry of Housing of Colombia to reactivate housing projects for all strata of the population, which date to mobilize more than 80 billion Colombian pesos (approximately USD $ 20.000 millions) in business in the next years related to construction of buildings and real estate activities; it is important to bear in mind that according to the lessons learned in the construction sector, it is difficult for project managers to manage all the areas of knowledge with an adequate rigor and level of detail. This can trigger problems for the project, especially if the project manager dedicates his efforts to managing areas of knowledge that do not impact the success of the project in a significant or direct way, Therefore, it is essential that project managers have adequate tools to make a reliable prioritization of the project management processes on which they should place greater emphasis given the characteristics of the project.

It should be noted that in the literature review and in the consultations with project managers, no recommendations, tools, techniques, methodologies, or good practices were found to support managers in prioritizing project management processes in vertical construction. Therefore, the purpose of this work focused on the design of a method for prioritizing the management of knowledge areas in vertical construction projects, from the diagnosis of the situation of the use of the PMI processes to provide a tool that supports the project manager in defining the processes to which they should focus their efforts for a specific project. The contributions of this work can be described as follows:

1. The description of the process followed to design a methodological guide for project management, which can be extrapolated to other sectors.
2. The design of the guide for the prioritization of process management of the knowledge areas contemplated by the PMI® in construction projects.
3. A practical tool that accompanies the guide for prioritizing process management.
4. The way the proposed guide is validated.

The paper is organized in the following sections: a review of related works in Section 2. In Section 3,presents a description of the methodology used in the proposed guide. In Section 4explains the proposed guide and its validation. Finally, Section 5 shows the discussion, conclusions, and future work.

II. RELATED WORK

The literature review conducted for this study was divided into three sections as follows:

A. Management of projects under construction and PMBOK

In 2023, Abdulnasser & Abdulmajid [14], carried out a study where they evaluated how much the PMBOK® Guide is applied and identified the factors that affect its application in construction in Yemen. In 2008, Bryde [15], reported in his article the results obtained after surveying 238 organizations in the UK. The surveys were applied with the objective of discovering the knowledge and maturity of the organizations, regarding project management. The document concludes that the construction sector has a more mature management in program management and organizational support for project management. However, it presents opportunities for improvement in management of benefits and sponsorships. In 2013, Chou & Yang [16] proposed a statistical modeling that consists of identifying a set of 87 indicators typical of different areas of knowledge. The study concludes that communications allow stakeholders and actors to converge in the development of the project and, in addition, provide a tool for direct and rapid collection of opinions. In 2017, Pacheco[17] and Betancourt [18] report case studies in which the methodology proposed in the PMBoK guide is applied to construction projects for educational services and a hotel, respectively. Within their conclusions, they ensure that the exact definition of the scope is essential for the control and subsequent success of the project. In 2019, Dixit et al. [19], carried out a systematic review related to the evolution of studies on construction productivity. From this review carried out in publications from 2006 to 2017, it was determined that research efforts have been particularly concentrated in seven large areas: (1) Study of factors and/or attributes; (2) Measurement techniques; (3) Simulations and models; (4) Equipment and technology; (5) Problems and issues related to productivity in construction; (6) Improvement techniques; and (7) Maturity of studies in the construction sector.

B. Methodologies, methods or prioritization guides

In 2015, Pereira[20], proposed a methodological guide for prioritizing the selection of projects of the VIDALCO SAS construction company. This prioritization methodology is divided into three phases: strategic, filtering and selection. The study concludes that the company does not have a goal fulfillment measurement system, so its employees are not aligned with the strategic plan. Also in 2015, Méndez[21], proposed a prioritization method, based on qualitative research, for technical risks associated with the execution of industrial floors in construction projects or the company. Finally, it concludes that the risks with the greatest impact and probability of occurrence are those associated with the designs of the foundation. In 2009, Zwikael [22], approached the prioritization of knowledge areas within the planning process, around the impact they have on the success of the project. The research allowed establishing a hierarchical order in which the management of time, risks, scope and human resources are decisive activities in the success of the management of the planning of a project. Finally, the document clarifies that this prioritization may depend on many variables - among others on the economic sector to which they belong.

C. Success and delay factors

En 2023, Mejía et al [23], classified the causes of delay in building and road construction projects, organizing them into 16 factors and seven management areas, they used a relative importance index for the classification, additionally, they generated recommendations to mitigate delays in projects related to the management of stakehoders. In 2019, Sepasgozar et al [24], conducted a study on factors that delay construction projects, information was taken from more than 29 countries, finding four factors (resources, project context, stakeholder performance, and external factors) that can be included in mitigation strategies. In 2017, Preethi & Manoharan[25], reported an investigation carried out in India, in which the importance of quality management in projects in the construction sector was studied. The authors conclude that, by controlling the quality requirements, companies will obtain higher economic rewards from a project. In 2018, Kuwaiti *et al.*[26] presented an investigation carried out in Abu Dhabi, regarding the key success factors in the construction of health sector projects. The study concludes that, for both clients and contractors, the collection and management of project financing are key to success. Also in 2018, Paz *et al* [27], presented a methodology for the evaluation of risks of delay in the schedule of construction projects. The study concludes that the importance of risks in construction projects varies with respect to their geographical and political location. In 2019, Arefazar *et al.* [28] presented a study of prioritization of techniques for management of change, used and recommended by agile methodologies in construction project management. The study concludes that the most effective techniques in change management are monitoring and continuous improvement of resources, flexible workflow, customer participation, opportunities for communication and receipt of requirements, and short-term planning.

III. METHODOLOGY

For the construction of the methodological guide for the prioritization of the management of processes of knowledge areas, three different phases were defined: the elaboration of the diagnosis, the formulation, structuring and programming of the prioritization tool and the validation of the tool. The description of each phase is presented below.

A. Phase 1: Elaboration of the diagnosis

The diagnosis of the current situation of the use of PMI processes in vertical construction project management was developed through the elaboration of a systematic mapping and the collection of lessons learned from project managers.

In the first instance, the systematic mapping was developed using the steps proposed by Petersen [29], which aimed to: "Examine the current state of knowledge about vertical construction project management, its relationship with the knowledge areas of the PMBOK [11] [13] and the identification of good practices, methods or methodologies for the prioritization of processes or areas of knowledge". The search string used was: "(construction) AND (project) AND (prior/prioritizing/prioritization)", which was applied to the databases: Google Scholar, Web of Science, Scopus, Scielo and Proquest. Since there are few studies related to the prioritization of processes in construction projects, the connected papers tool was used to broaden the previously obtained search. After applying selection and quality criteria, 32 papers were selected, which were taken as the basis for the design of the proposed guide, if their results point to prioritization already made by authors and identification of key factors of success and failure.

In the second instance, the collection of the lessons learned was carried out by applying a survey to experts in the management of vertical construction projects, to extract information on: (1) the use and management of the processes proposed by the PMBoK; (2) the perception of the importance of knowledge areas for vertical construction project managers; and (3) expert considerations for key success factors and common problems in vertical construction projects. The steps followed to collect the lessons learned were:

1. Design [30] which involved defining: (1) the objective of the survey as follows: *"Collect information related to the practical and empirical development of construction projects, to identify possible links with the application of good practices in their management "*, (2) the focus of the survey defining the use of qualitative and quantitative variables; (3) the subjects to be surveyed: *"professionals in the areas of civil engineering and architecture, construction project managers, managers and legal representatives of the vertical construction industry"*; (4) the instrument, prepared in a form from Google Forms; (5) the hypothesis: *"establish the state of the respondents' knowledge of good project management practices"*; (6) logical sequence, the survey addresses the issues from the general to the particular; (7) coding, the survey has sections for collecting data from the respondents and the questions grouped according to the interest in extracting the information described in the previous paragraph; (8) questions are closed and open; and (9) the sample, a non-probabilistic sampling of project managers of micro and small vertical construction companies located within the northern savanna of Bogotá was carried out.
2. Application. The survey was applied by sending emails. It should be noted that due to the issue of the pandemic it was not possible to carry out the survey directly.
3. Analysis of results. The findings are described below:

- The responses to the surveys show that all the respondents presented the suitability to give an answer. The group was divided between architects and civil engineers. Most of those surveyed had participated in more than 8 vertical construction projects and had been part of projects with amounts exceeding five hundred million pesos, in which cases 57% of the roles practiced were as project manager.
- 57% of those surveyed applied good practices in the development of construction projects. Within the guides and good practices identified by the project managers, we found that they refer to the management of the triple restriction (scope, time, cost) and the management of resources and risks. 71.4% of those surveyed knew the extension for the construction of the PMBoK, and the usefulness of the processes proposed by the PMI is relative for the group. 28% of those surveyed considered that they were not useful, in part because the application of all of these is complex within the development of the project. On the other hand, for 71% of the experts, the application of the processes within the management of vertical construction projects was very useful.
- There was a particular point at which all respondents converged and that is the need to prioritize the management processes of vertical construction projects. None of the experts exhibited a clear method of prioritization of processes in vertical construction projects. However, they claim to do so with respect to particularities of each project,

that is, they identify characteristics of the projects and select or prioritize the projects in function of dependent variables of the same project.

- Table 1 shows the qualification given by the experts to the level of importance of each area of knowledge towards favoring the success of the project, according to the experience of each one. From this assessment, management of project costs stands out, followed by management of project financing, quality management, the schedule, and the scope, then management of the integration of the project, followed by management of risks, acquisitions, stakeholders and safety, health, and environment. Finally, management of resources and management of project communications are the least valued.

Table 1. Classification of level of importance of areas of knowledge according to expert criteria. **Source:** self-made

Area of knowledge	Impact assessment
Project Integration Management	4.2
Project Scope Management	4.4
Project Schedule Management	4.4
Project Cost Management	4.6
Project Quality Management	4.4
Project Resource Management	3.8
Project Communications Management	3.4
Project Risk Management	4
Project Procurement Management	4
Project Stakeholder Management	4
Project Safety, Health and Work Environment Management	4
Project Financing Management	4.5

Finally, the diagnosis was made using a SWOT analysis [31] for the diagnosis of current situations and a starting point in making important decisions, which is presented in Section 4.

B. Phase 2: Construction of the guide

In this phase, a prioritized tool was formulated, structured, and adapted on an Excel calculation document, which was executed divided into several moments.

- Moment 1. Assignment of scores according to lessons learned from expert judgment in relation to two criteria: the weight given to the areas of knowledge and the extraction of problems and success, and failure factors formulated by the experts.
- Moment 2. The criteria found in the literature documents are organized and their assignment to a maximum of two areas of knowledge and two processes.
- Moment 3. The success and failure factors are combined into questions that are evaluated between one and five.
- Moment 4. Scores are assigned and weighted according to the prioritization in the documents reviewed at moment 2 and the evaluation at moment 3.
- Moment 5. The results obtained by areas and project management process are presented. It is worth mentioning that the columns of the instrument are classified by color.
- Moment 6. Organization of scores from highest to lowest indicating the processes with the highest score.

C. Phase 3: Validation and adjustment of the tool

The validation of the tool that supports the constructed guide was carried out through the implementation, adjustment, and evaluation, through the inspection of the expert judgment and the analysis of the perception of the experts carried out with a sentiment analysis tool.

It should be clarified that Sentiment Analysis (SA) is a technique that combines information retrieval and computational techniques to analyze points of view that are expressed in texts or documents [26, 27]. The classification of a feeling in a text can be determined by the polarity of an opinion valued as positive, neutral, or negative about a product, service, or

any type of text [32]. The calculation of the polarity of a text is presented as a real number in the range of [0, 1], for each polarity value (positive, neutral, and negative) [34].

IV. RESULTS

Below, the results obtained in each phase are presented to establish the process to build the guide and the development of the instrument for prioritizing the project management processes.

A. *Diagnosis of the current situation in the use of PMI processes in vertical construction projects Making of query strings*

To diagnose the current situation in the use of PMI processes in vertical construction projects, a SWOT matrix was prepared, presented in Tables 2 and 3, based on the results of the systematic mapping and the collected lessons learned.

Table 2. SWOT matrix (Part 1). **Source:** self-made

Strengths	Opportunities
There is maturity on the part of the construction sector in the knowledge of the good practice guide proposed by the PMI	Several of the research studies published on project management today dedicate their efforts to prioritizing the importance or impact of processes on the success of the project.
There are proposals for the management of construction projects such as the extension for the construction of the PMBoK.	There are several types of studies that have already prioritized process management based on specific conditions or populations within the construction sector.
There is the suitability of directors for project management under the guidance of good practices from PMI. Several of the respondents both in selected studies and in the collection of lessons learned have postgraduate degrees in project management.	Both the literature and the collection of lessons learned from experts, documents, and records the need to prioritize process management in construction projects. In addition, it was observed that the surveyed experts assign different levels of importance to the knowledge areas proposed by the PMBoK.
	The PMBoK guide allows the project manager to adapt the processes selected to apply, as well as the degree of rigor with which they must be managed, given the diversity and specificity of each project.

Table 3. SWOT matrix (Part 2). **Source:** self-made

Weaknesses	Threats
There are no methods, guides, tools, or methodologies for prioritizing process management based on the requirements or conditions of a specific construction project.	Several of the research studies published on project management today dedicate their efforts to prioritizing the importance or impact of processes on the success of the project.
According to the lessons learned, generally in vertical construction projects of smaller amounts, there is a shortage of human resources that allows the equitable management of all the areas of knowledge and processes contemplated by the PMBoK.	It is identified in the literature and in the lessons learned that certain construction managers move away their contractual requirements from the planning phases and definition of reliability requirements for the execution of construction projects.
Some experts consider that the management of processes is complex, and, in some cases, it is reduced to the incomplete management of the areas of knowledge.	Several of the research studies published on project management today dedicate their efforts to prioritizing the importance or impact of processes on the success of the project.

To create the guide, methods were used to assign weights of importance, probability of occurrence or relationship in terms of impact or dependency. The assigned weights were consistent with the result of the success or failure factors reviewed both in the literature and in expert judgment.

B. *Guide for the prioritization of the management of processes and areas of knowledge*

To provide a methodological guide so that the use of the prioritization tool can be extended, Figure 1 presents a summary of the methodology that guides the steps for formulation, structuring, and validation, where what is done at each moment is described. It should be noted that the steps presented here can be extrapolated applicable to different sectors and their adaptation can be carried out following the phases presented in Section 3.

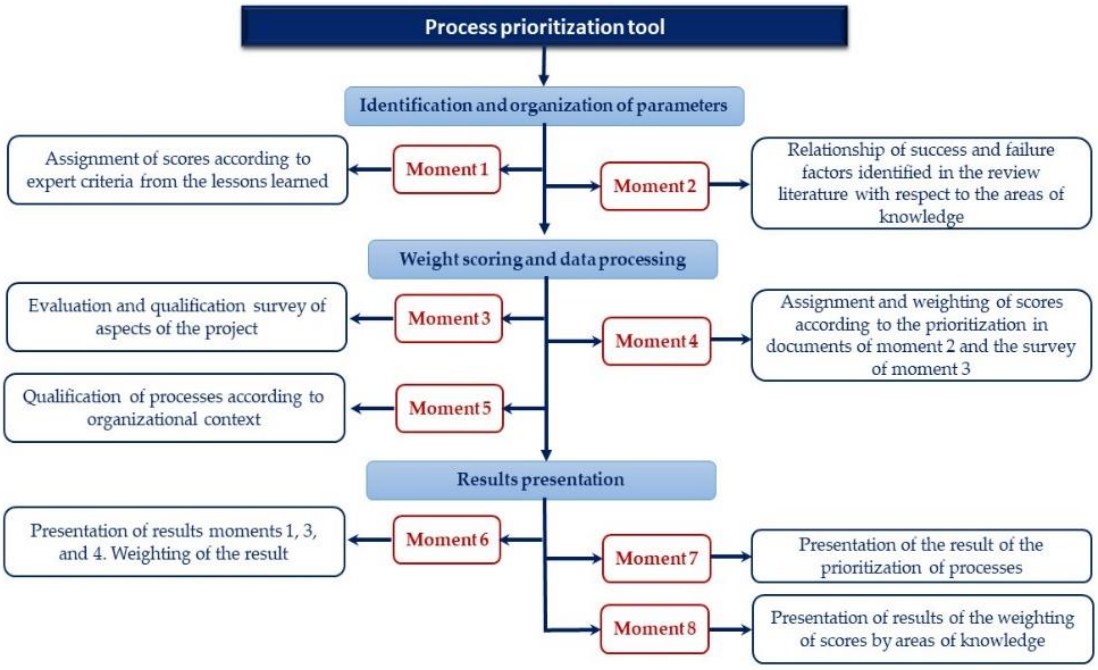
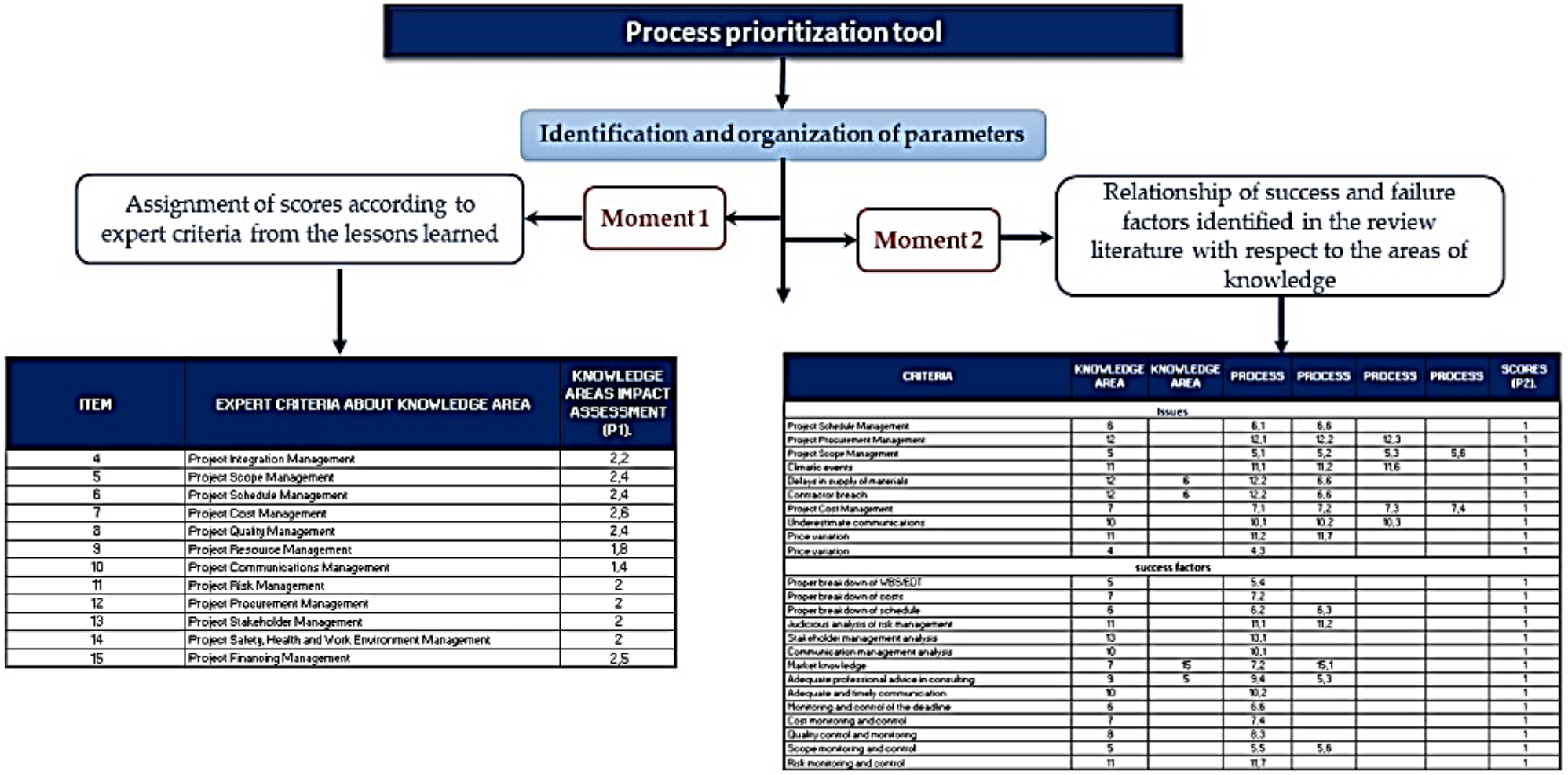


Fig. 1. Summary of phases and moments of the guide for the prioritization of processes and areas of knowledge. **Source:** self-made.

In the Link (https://cutt.ly/3EBDpjq), there is the prioritization tool formulated in Excel format. This tool supports each of the moments presented in the flow diagram presented in Figure 1.

In Figure 2, a screenshot of moment 1 and 2 of the tool described above is presented.

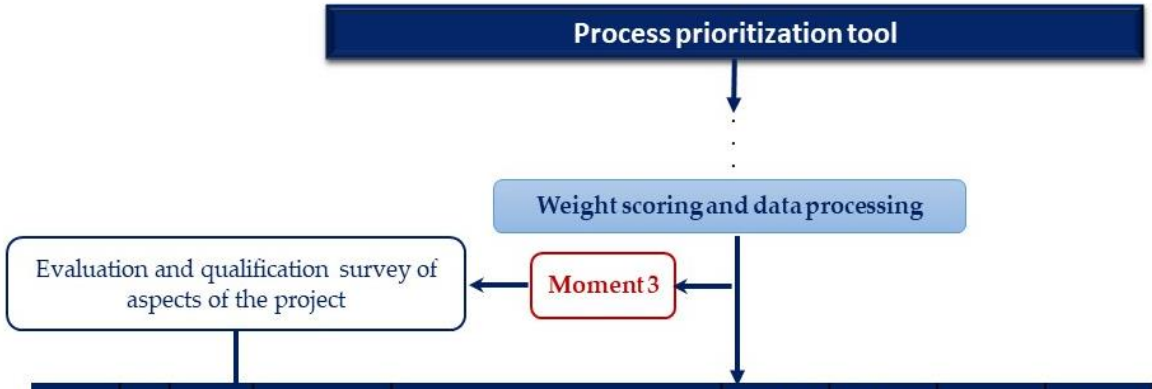


ITEM	EXPERT CRITERIA ABOUT KNOWLEDGE AREA	KNOWLEDGE AREAS IMPACT ASSESSMENT (P1).
4	Project Integration Management	2,2
5	Project Scope Management	2,4
6	Project Schedule Management	2,4
7	Project Cost Management	2,6
8	Project Quality Management	2,4
9	Project Resource Management	1,8
10	Project Communications Management	1,4
11	Project Risk Management	2
12	Project Procurement Management	2
13	Project Stakeholder Management	2
14	Project Safety, Health and Work Environment Management	2
15	Project Financing Management	2,5

CRITERIA	KNOWLEDGE AREA	KNOWLEDGE AREA	PROCESS	PROCESS	PROCESS	PROCESS	SCORES (P2).
Issues							
Project Schedule Management	6		6,1	6,6			1
Project Procurement Management	12		12,1	12,2	12,3		1
Project Scope Management	5		5,1	5,2	5,3	5,6	1
Climatic events	11		11,1	11,2	11,6		1
Delays in supply of materials	12	6	12,2	6,6			1
Contractor breach	12	6	12,2	6,6			1
Project Cost Management	7		7,1	7,2	7,3	7,4	1
Underestimate communications	10		10,1	10,2	10,3		1
Price variation	11		11,2	11,7			1
Price variation	4		4,3				1
success factors							
Proper breakdown of WBS/EDT	5		5,4				1
Proper breakdown of costs	7		7,2				1
Proper breakdown of schedule	6		6,2	6,3			1
Judicious analysis of risk management	11		11,1	11,2			1
Stakeholder management analysis	13		13,1				1
Communication management analysis	10		10,1				1
Market knowledge	7	15	7,2	15,1			1
Adequate professional advice in consulting	9	5	9,4	5,3			1
Adequate and timely communication	10		10,2				1
Monitoring and control of the deadline	6		6,6				1
Cost monitoring and control	7		7,4				1
Quality control and monitoring	8		8,3				1
Scope monitoring and control	5		5,5	5,6			1
Risk monitoring and control	11		11,7				1

Fig. 2. Summary of phases and moments of the guide for the prioritization of processes and areas of knowledge. Own elaboration.

In Figure 3, a screenshot of a section of moment 3, where the criteria extracted from one of the papers selected in the systematic mapping are used, which are used to ask the evaluation question to assign scores considering their relationship with two areas of knowledge and two processes.



PRIORIZATION	CODE PAPER	DOCUMENTS	CRITERIA	ASSESSMENT QUESTION	FIRST AREA OF KNOWLEDGE VITH VHICH THE FACTOR IS RELATED	SECOND AREA OF KNOWLEDGE VITH VHICH THE FACTOR IS RELATED	FIRST PROCESS VITH THE FACTOR IS RELATED	SECOND PROCESS WITH THE FACTOR IS RELATED	RELATIONSHIP VITH PRIORITIZATION	SCORE ASSIGNED	QUALIFICATION FOR PRIORITY TABLE (SP2)
1	GS8	CAUSES OF DELAYS IN THE CONSTRUCTION PHASES OF CHINESE BUILDING PROJECTS	Delays in progress payments	Evalué de 1 a 5 la vulnerabilidad del progecto ante la probabilidad de demoras en el progreso de los pagos	15		15,1		Directa		0
2			Labor shortage	Evalué de 1 a 5 la vulnerabilidad del progecto ante la probabilidad de escasez de mano de obra para la ejecución del progecto.	9		9,4		Directa		0
3			Rework due to errors during construction	Evalué de 1 a 5 la probabilidad de que se presenten reprocesos debido a errores durante la construcción	4		4,3		Directa		0
4			Client interference	Evalué de 1 a 5 la interferencia que se pronostica tendrá el cliente dentro del progecto	13		13,3		Directa		0
5			Insufficient authority delegated to engineer by client	Evalué de 1 a 5 la autoridad que tiene la persona delegada por el cliente para el gestión del área de ingeniería	9		9,4		Directa		0
6			Contractor lack of capital	Evalué de 1 a 5 la disposición de capital para la ejecución del progecto por parte del contratistas	11	15	11,4	15,1	Inversa		0
7			Exceptionally low bids	Evalué de 1 a 5 la exactitud de la oferta y la vulnerabilidad ante el impacto del presupuesto debido a imprevistos.	11	7	11,4	7,3	Directa		0
8			Unqualified workforce	Evalué de 1 a 5 la disposición de mano de obra calificada para la ejecución del progecto	9		9,3		Inversa		0
9			Delay caused by nominated subcontractor	Evalué de 1 a 5 la vulnerabilidad del progecto ante retrasos que puedan generar los subcontratistas	4	6	4,5	6,6	Directa		0
10			Variations/changes of scope	Evalué de 1 a 5 la probabilidad de cambios en el alcance del progecto.	4	5	4,6	5,6	Directa		0
11			Delay caused by domestic subcontractor	Evalué de 1 a 5 la vulnerabilidad del progecto ante los retrasos generados por subcontratistas locales	4	6	4,5	6,6	Directa		0
12			Slowness in decision-making process by client	Evalué de 1 a 5 la rapidez del proceso establecido por el cliente para la toma de decisiones	10	4	10,2	4,6	Inversa		0
14			Project stakeholders breach the contract	Evalué de 1 a 5 la probabilidad de incumplimiento del contrato por parte de las partes interesadas.	4	12	4,1	12,2	Directa		0
15			Inaccurate bills of quantities	Evalué de 1 a 5 la eficiencia del plan para el control de las cantidades de	4		4,5		Inversa		0
16			Contractor ' s construction manager	Evalué de 1 a 5 la idoneidad del director de la construcción suministrado por el contratista	9		9,4		Inversa		0
17			Inexperienced contractor	Evalué de 1 a 5 la esperiencia del contratista en progectos de construcción.	11	5	11,2	5,2	Inversa		0
18			Poor qualification of the contractor ' s technical staff	Evalué de 1 a 5 la logística técnica del contratista	4		4,5		Inversa		0
19			Poor planning and scheduling by contractor	Evalué de 1 a 5 la madurez en los procesos de planeación del contratista	12		12,1		Inversa		0
			Original contract duration is too	Evalúe de 1 a 5 la vulnerabilidad del progecto ante fallas practicas del							

Figure 3. Section of moment 3 where used an assessment question to find the relationship with knowledge area and process. Own elaboration.

The rest of the tool presents each moment described in Figure1, so that at moment 7 the results of the prioritization of processes and knowledge areas are obtained. The tool is in this link: https://cutt.ly/3EBDpjq

C. *Evaluation of the proposed guide using sentiment analysis*

The validation and evaluation of the proposed guide was carried out through a face-to-face or virtual meeting with experts. This validation process consisted of three steps:

In the first instance, an explanation of the proposed prioritization guide was made to a group of experts willing to comment on it.

In the second instance, the use of this, its application and the rapid tests that are available are left at the disposal of the experts. In the third instance, four (4) questions were defined that allowed us to analyze the perception of the experts, as follows: Q1: Indicate what you liked the most in the proposal of the guide for the prioritization of knowledge areas and management processes of construction projects. Q2: Mention the negative aspects or limitations that you perceive in the practical application of the prioritization guide. Q3: Is it clear to you how the tool obtains, processes data, and returns results? Q4: Would you put the tool into practice, prior to starting your construction projects, to prioritize process management?

Finally, using a sentiment analysis tool, the polarity of the perceptions received from the experts was evaluated.

The tool developed for the processing of the texts of the answers of the experts was perfected especially for this degree work by the experts Dr. Gabriel Elías Chanchí, Dra. Luz Marina Sierra Martínez, and Juan Francisco Cuestas, based on the tool developed in [34]. The tool presents a graphical interface that allows you to view the results of the polarity analysis and a graph of the results obtained. The development of the tool was carried out in Java. It uses the Parallel Dots API (https://www.paralleldots.com/technology) in the background, and the Java JFreeChart library to graphically represent the polarity values of the responses. from the experts.

The operation of the tool begins with the loading of the answers to the questions of perception of each expert through a text file. The tool then displays the answers in the graphical interface, in the "Loaded Answers" tab, as shown in Figure 4.

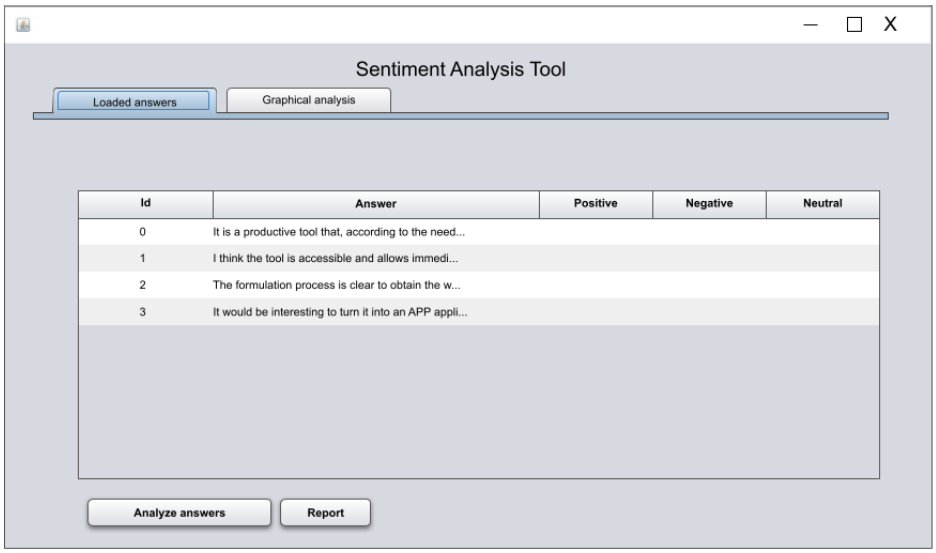


Fig. 4. Main interface of the sentiment analysis tool. Source: Own elaboration.

Then, with the "Analyze Responses" button, the responses are processed. With the "Report" button, you can download a file in .csv format. This can be seen in Figure 5.

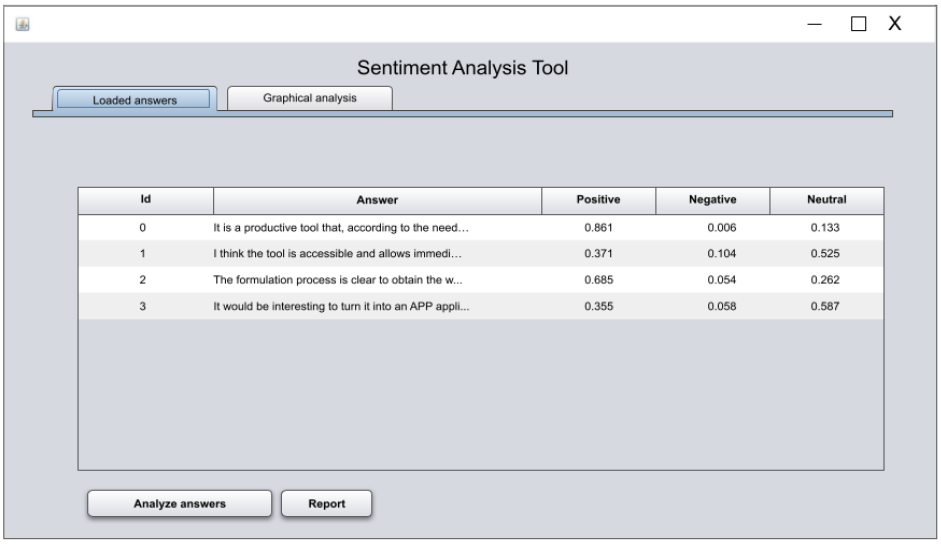


Figure 5. Interface of the processed responses tab. Answers of Expert 1. Source: Own elaboration.

Finally, in Figure 6, the "Graphical analysis" tab is presented, in which the graph of the polarity of each response is generated.

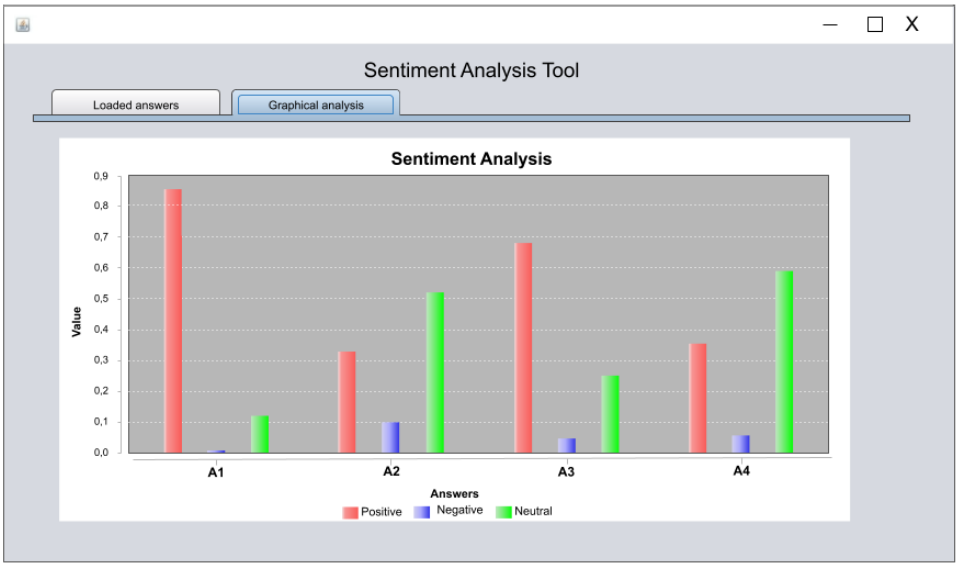


Fig. 6. Graphical analysis tab interface. Answers of Expert 1**.** Source: Own elaboration.

In the case of expert 1, in the previous figures, in general his appreciations have a positive trend as follows: Question 1, positive polarity 0.861; Question 2, slight difference between positive (0.371) and neutral (0.525) polarity; Question 3, positive polarity 0.685; and Question 4, neutral polarity 0.587.

At the general level of the experts who used and validated the tool, the following result was obtained: Question 1, for all the experts the polarity had a positive trend, higher than 0.5, that is, there is no negative trend. All the experts liked the guide presented. Question 2, although it asks about negative aspects or limitations of the guide for two users, the trend is neutral and for the others it was positive polarity. Question 3, two experts tended to be neutral while one of the experts was very positive about the clarity of the proposed guide. Question 4 has a very clear tendency towards positivity, that the experts are willing to use the proposed guide.

As could be seen in the perception evaluation carried out, the generated tool makes it easier for project managers to prioritize project management processes, and thus focus on those that are most relevant to the success of a specific project. The managers who evaluated the proposed guide had a generally positive perception about the suitability of the guide and the proposed tool. Taking into account that building construction is very similar around the world and faces the same risks, challenges and difficulties, making the results of this research work applicable to a variety of vertical construction projects. . The above added to the fact that the method with which the guide and the tool were obtained was rigorous and allows its application to generate specific guides in other construction contexts or other areas of application of good practices in construction management. projects proposed by the PMI.

V. CONCLUSIONS

The use of PMI processes in vertical construction project management is directly related to the knowledge of the directors or construction project management group. However, through the results obtained in the systematic review and in the set of applied surveys, it can be concluded that there is maturity in the knowledge of good practice guides and management of most of the processes contemplated by the PMBoK and its extension for the construction. This application of processes is generally biased to the set of contractual requirements of the project and to the theory of the triple restriction associated with knowledge areas related to the cost, the schedule, and the scope of the project.

It is also identified that the use of processes is limited by the project's own human resources. In this measure, it was determined that in practice a certain prioritization of the management of some processes is carried out by the project managers. However, this prioritization is carried out without the guidelines of a guide or tool.

The proposed methodological guide allows prioritizing the management of processes of knowledge areas, based on four key aspects: expert criteria, prioritization of success and failure factors recorded in the literature, particular characteristics of the project to prioritize processes, and organizational context based on its strategic plan.

The method for the construction of the prioritization methodological guide was composed of 3 phases: Diagnosis of the current situation in the use of PMI processes in vertical construction projects, presented through a SWOT matrix; Construction of the guide, which included the formulation, structuring and programming of the prioritization tool using Excel; and finally, the validation of the tool with expert judgment and analysis of perceptions. This is a method that can be extrapolated to all contexts.

In general terms, experts credit the usefulness of the tool, and state that they would use it in construction projects. Two of the experts highlight the productivity of the tool within the real requirements that construction projects have daily. Moreover, some limitations are identified such as the practicality in the application of the guide. Therefore, as future work there is the development of an App that allows entering data and obtaining results.

Finally, for all the experts it was clear how the guide obtains and processes data to produce results. Also, in the perception analysis a positive trend was detected in relation to the liking, acceptance, understanding and use of the proposed guide carried out by polarity classification with the tool developed for this purpose. The proposed guide allows the project manager to find a clearer picture of the way in which he can focus his efforts and knowledge to process management, which impacts the success of a project.

At the level of the aspects to be improved in the guide, no negative trend was detected, that is, although it was expressly asked about limitations or aspect, the perceptions were neutral.

VI. CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Juan Francisco Cuestas Ramírez: conceptualization, methodology, investigation, writing—original draft preparation, visualization, and resources**; Luz Marina Sierra-Martínez:** investigation, supervision, and project administration, writing—review and validation; **Gabriel Elías Chanchí-Golondrino** interpretation of the data, writing—review, and validation. All authors read and agreed to the published version of the manuscript.

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