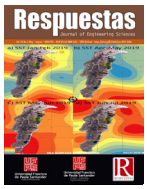

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Characterization of maturity in civil construction works in Colombia

Caracterización de la madurez en obras de construcción civil en Colombia

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ABSTRACT

Keywords:

Intersection. Roundabout.
Turbo-roundabout.
Signalized intersection.
Overpass.
traffic.
Stochastic tracking model.
Micro simulation.
VISSIM.

Project management is one of the disciplines with the greatest academic interest in recent years, due to the importance of projects for the economy and strategic positioning of both an organization and a region or country. The maturity of project management in organizations is related to the search for a competitive advantage in the market through excellence in the projects and various models of maturity have been proposed in the organizations. The objective of this study is to characterize the maturity in the management of construction projects in Colombia, based on the perception of a representative sample of project managers in the sector. The results show that, at each of the maturity levels, such as standardization, measurement, control, and continuous improvement, project managers, mostly the project management processes, have techniques and tools for project management implemented. However, the basic orientation of construction project management towards the processes of knowledge areas that make up the so-called iron triangle of projects, such as scope, schedule, budget, and quality, is evident. The results of this research show the need to implement appropriate strategies by construction companies to improve the level of maturity in processes related to the management of resources (mainly human resources), project knowledge management, risk management, and communication management among the different stakeholder groups of the project, to increase the success rate of projects in this sector. the construction.

RESUMEN

Palabras clave:

Compuestos volátiles,
Factor de respuesta,
SPME,
Índices de Kovats,
GC-MS,
licor de cacao.

La gestión de proyectos en una de las disciplinas con mayor interés académico de los últimos años, debido a la importancia de los proyectos para la economía y posicionamiento estratégico tanto de cualquier tipo de organización como de una región o país. La madurez en gestión de proyectos en las organizaciones, está relacionada con la búsqueda de una ventaja competitiva en el mercado por medio de la excelencia en los proyectos y se han propuestos diversos modelos de madurez en las organizaciones. El objetivo de este estudio es caracterizar la madurez en la gestión de proyectos de la construcción en Colombia, basados en la percepción de una muestra representativa de directores de proyectos del sector. Los resultados demuestran que, en cada uno de los niveles de madurez, tales como la estandarización, la medición, el control y la mejora continua, los directores de proyectos en su mayoría los procesos de la gestión de proyectos cuentan con técnicas y herramientas de gestión de proyectos implementadas. Sin embargo, es evidente la básica orientación de la gestión de proyectos de la construcción hacia los procesos de áreas de conocimiento que constituyen el llamado triángulo de hierro de los proyectos, como son el alcance, el cronograma, el presupuesto y la calidad. Los resultados de esta investigación ponen de manifiesto la necesidad de implementar estrategias adecuadas por parte de las empresas constructoras para mejorar el nivel de madurez en procesos relacionados con la gestión de recursos (principalmente los recursos humanos), la gestión del conocimiento del proyecto, la gestión de los riesgos y de la gestión de la comunicación entre los diferentes grupos de interesados del proyecto, con el fin de amentar la tasa de éxito de proyectos en este sector de la construcción.

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Introduction

The maturity in project management of organizations is related to the search for a competitive advantage in the market through excellence in projects [1]. The way to achieve this objective is best described using maturity models in project management, which are composed of stages that relate the base and the necessary elements that must be correct for an organization to be able to move from one level of maturity to the next [2]. Thus, the implementation of good project management practices and their use for a long time is a necessary but not sufficient condition to achieve excellence.

According to Solarte and Sánchez [3], the term of maturity in project management began to be used from the moment in which Dr. Harold Kerzner defined it in the publication of the book "Using the Project management Maturity Model. Strategic planning for Project management ", conceptualizing it as a model of organizational maturity that constitutes the basis for achieving excellence in project management organizations. According to this definition, the maturity of a project is related to achieving a level of fulfillment or reaching the maximum point of its progressive development.

In this way, the management of projects in the organizational order is related to the ability to recognize their current point of maturity, comparing it with a standard of progressive development towards higher stages. Under this precept, the initiative of the maturity models for project management dates back to the 80s, more precisely towards November 1986, when the Software Engineering Institute (SEI) with the sponsorship of the Ministry of Defense United States, develops a process maturity model in software development and as a result of this work, the first process evaluation model known as Capability Maturity Model (CMM) [4] was born.

In this way, the models of maturity allow organizations to quantitatively assess the level of management and compare this with other organizations, building or elaborating strategies, identifying problems, optimizing resources, and leading processes of continuous improvement both internally and externally. [4]. According to Arce Labrada and López Sierra [5], over the years, project management and organizational maturity are essential to achieve success in any organization, to the extent that projects can be constantly evaluated and controlled, where its benefits are measured in the improvement of time, budgets, life cycles, quality and productivity of projects, customer satisfaction, employee morale and return on investment as well as cost reduction.

Maturity models are seen as strategic tools used by senior managers to identify areas for improvement and prioritize improvement actions [6]. These models originate in the successful application of the principles of quality management techniques in manufacturing processes. Specifically, the idea of maturity originated in the domain of process improvement where it is believed that processes can predictably function as controllable systems. Process capability models apply this idea and define the process capability as "the quantifiable range in which a process can continue to obtain the expected results" [7].

Consequently, maturity models take the concept |that the result of a statistically controlled process is different from those of uncontrolled processes [8], and use it to support that the results of a process will be affected by the degree of that the organization can implement specific practices associated with each level of maturity. However, the models have been developed over time to go beyond the capacity of the process only, first incorporating the capacity and competence of the personnel involved in the processes [9], and then the requirements of project management [10] [11].

The concern for maturity in project management has taken on importance in organizations, thanks to the consideration of projects that represent an adequate way to transform a complex situation into a profitable opportunity [12] Thus, the concept of maturity in project management has been linked to the potential for success or failure of projects, suggesting that immature organizations that are characterized by improvisation in the GP, without establishing necessary connections between projects. they are more likely to not have good results in the efficiency and effectiveness of their interventions [13]. When analyzing, if when organizations systematically adopt GP practices, they manage to advance in the levels of maturity obtaining as a benefit a better performance of their projects and studies on the application of mature models of information technology (IT), especially about The CMM and CMMI models have concluded that these models tend to develop high-quality software, a faster development cycle, higher productivity,

better organizational performance and significant project success increase just more beyond level 3 of the CMM [14].

In an intersectoral study in the USA, in [15] it is concluded that maturity in project management is not only associated with organizational performance, but can also influence the performance of the organization when it is integrated into the culture.

In this same direction, among the large construction companies in Iran, only those that have reached high levels of maturity have been able to win contracts for international projects [17].
n the local context, within the Colombian business sector, other studies have been carried out that aim to assess the maturity of companies, as is the case of the study presented by [18], who assess the degree of maturity in a sample of 226 SMEs over 10 employees, through a survey on the degree of compliance with standardization, measurement, control, and continuous improvement processes, as well as the interrelation between their real projects and their service portfolio, concluding that the level of maturity of projects in companies large is 46.9% and this level is reduced proportionally to the size of the companies where microenterprises only reach a degree of maturity of 6.2%.

Specifically in the construction sector as Bohórquez, Mondragón, Rodríguez, and Castillo [19], present a study, which assesses the level of maturity in project management of 8 companies in the construction sector in Bogotá, through direct observation, where the diagnosis of each company is corroborated with 77 interviews made to medium and low-level employees of these 8 construction companies, evidencing that knowledge about the maturity of project management is proportional to the position and that It is necessary to standardize a tool designed to focus the effort to individually improve each of the processes that are part of the project's life cycle.

The construction sector in Colombia has been one of the main drivers of the growth of the national economy, mainly due to the growth dynamics during the last three decades of projects and macro projects in civil works, this is how in 2018, the growth of the Gross Domestic Product was 2.5%, concerning the previous year and construction was one of the sectors that contributed the most to this growth, according to a report from the National Department of Statistics DANE [20]. However, the study of the management of construction projects has been a subject of constant interest in the scientific literature due to its high failure rate due to delays and cost overruns, in Colombia, the most important factors of this problem have been identified as inadequate planning and lack integration among professionals [21].

At the level of individual companies, Acevedo, Esquivel, and Sánchez [22], as well as Sabogal and Mayer [23], have presented projects that are based on the validation of the degree of maturity reached by each company, emphasizing the need to adopt oriented policies to improve the level of maturity in project management, which have been evaluated under the methodologies. A survey that was prepared under the guidelines proposed by the ISO 21500 standard and the guidelines of the Organizational Project Management Maturity Model (OPM3) and Project Management Institute Inc. (PMI) is used as an observation instrument.

Currently, there are several models of project management maturity, most of which have been developed by consulting firms [24]. A good part of these models have been created during the last two decades, although some existed previously, for example, the Capability Maturity Model (CMM) and the Capability Maturity Model Integration (CMMI) [25], the Project Management Process Maturity Model [26], the Maturity Model of Project Management [27], the Organizational Model of Maturity in Management projects [28] and Project Management Competency Model PM [29]. Including the previous models, Grant and Pennypacker [30] have estimated more than 30 models available in the market, some dedicated to specific sectors of the industry such as SPICE (Structure Process Improvement for Construction Enterprises) [31].

Given the wide dissemination and acceptance in Colombia of the project management guide of the Project Management Institute PMI, this work aims to identify and describe the current level of maturity of project management in the construction sector, based on the OPM3 model of the PMI. The Organizational Maturity Model for Project Management (OPM3) was created by the PMI between 1998 and 2003, to provide a way for organizations to understand project management, and to measure maturity in contrast to a complete

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and comprehensive set of best practices in project management [28]. The OPM3 model establishes the requirements to guarantee and develop capacities in the domains of projects, programs, and portfolios to help organizations in the fulfillment of the strategies of the organization through projects [32].

Materials and methods

The different variables considered in the study related to the degree of maturity in the management of construction projects in the Colombian context are measures according to the perception of project managers. The variables related to the standardization of the processes corresponding to each of the areas of knowledge of the project management guide of the PMI, were sized and operationalized according to a scale of five levels, as follows: 1) sporadic use, 2) limited application , 3) implemented, 4) checked, and 5) optimized. Also, the study seeks to describe the current situation of these variables in the cited context and seeks relationships between them, therefore, this research is quantitative, exploratory, and correlational [33]

The population defined for this study is made up of project managers from the construction sector in Colombia. The design of the data collection instrument is an adaptation of the instrument used by [5] in 43 questions to understand on one hand the groups of processes and on the other the areas of knowledge defined in the project management guide of the PMI. These questions were defined in the five-level ordinal measurement scale described above in a multiple-choice format. The first section of the questionnaire collects the sociodemographic data of the engineer participating in the study. The second section is dedicated to measuring the perception of construction project managers against the degree of stenciling of each of the areas of knowledge in the domain of project management according to the PMI guide. The third section of the questionnaire is dedicated to measuring the perception of project managers regarding the degree of measurement of processes. The fourth section of the questionnaire gathers the perception of the project managers regarding the maturity in the control of the processes and finally, the fifth section is devoted to collecting the perception of project managers about the continuous improvement of the processes.

A pilot study was conducted in which 28 project managers from the construction sector participated in recent experience in different types of projects in this sector. The composition of the participants was 33% women and 67% men; 75% of project managers work in large construction companies, while 25% in small companies; 65% of the project managers work in the city of Bogotá and the rest distributed in Boyacá and Cundinamarca; the average experience was 5.48 years with a standard deviation of 2.84. The pilot study made it possible to improve the wording of some of the questions in the questionnaire. The data obtained from the pilot study were made an exploratory factor analysis and an analysis of the Cronbach alpha index. The results of these two analyzes allowed confirming the validity of the information collection instrument, related to the fact that the questions or variables are grouped into factors that directly reflect the interests of measuring the degree of maturity in the domain of project management in the sector of Construction in Colombia.

Taking into account that the population under study is large, the size of a representative sample was calculated. Simple random sampling is applied to obtain a resulting sample size of 68 project managers in the construction sector, from the recommendations of [30] for a scenario of maximum variability, using equation (1). Once the sample size was defined, we proceeded to consult the database of companies in the construction sector in Colombia, supplied by the "Cámara Colombiana de la Construcción CAMACOL" for the selection of the members of the sample. The selection of the sample was made through a simple random process and the means of distribution of the questionnaire was email.

$$n = \frac{Z_{\alpha}^{2} * p * q}{e^{2}}. \quad (1)$$

Where:
p=q=0.5 correspond to the probability of success and failure respectively
α or level of significance of 5%
Z value associated with the normal distribution corresponding to the level of significance
e or maximum estimation error of 0.10

Results

Considering a non-response rate, a total of 120 questionnaires were sent, of which 74 were received correctly. The first activity of the data analysis was the purification to identify extreme values and double answers to some of the 43 questions that make up the questionnaire. As for the demographic analysis of the sample, we have: 70% of the project managers are men and the rest are women; 25% of project managers work in large construction companies and the rest in small and medium-sized industries; 78% of respondents have directed housing construction projects and the rest in construction projects for shopping centers and offices; 93% of the participants in the study have more than 5 years of experience as construction project managers; 40% of the participants have certifications in project management; in terms of the geographical location of the projects, 37% corresponds to the center of the country, 33% to the north; 18% to the west and the remaining 9.4% of the projects are located in the eastern part of the country; and the average age of the participants is 38.4 years with a standard deviation of 6.12 years.

The first analysis of the results focuses on the lowest level of maturity in project management, such as the standardization of processes. For this, the processes corresponding to the knowledge areas of the Project Management Guide Body of Knowledge 6th edition were taken as reference. Table I summarizes the degree of standardization of the processes of the knowledge areas of project management, according to the perception of construction project managers. The values recorded in the cells of tables I, II, III, and IV correspond to the percentage of project managers. According to the results of Table I, it is evident that the processes related to knowledge management are the least standardized in this type of project. Also, it is worrying that the processes of very important areas during the life cycle of these construction projects such as risk management, quality management, and resource management (mainly human resources) were highly qualified as sporadic use or limited application. On the other hand, the processes with the highest degree of maturity, at the level of optimization, according to the perceptions of the participants, correspond to the knowledge areas such as integration management, scope, schedule, and budget, that is, those associated with the iron triangle of projects.

Table I. Maturity in process standardization

STANDARDIZATION OF PROCESSES	SPORADIC USE	LIMITED APPLICATION	IMPLEMENTED	CHECKED	OPTIMIZED
Integration management	10,9	10,9	26,6	40,6	10,9
Scope management	8,1	13,5	27	40,5	10,8
Calendar management	5,5	9,6	30,1	35,6	19,2
Budget management	8,1	10,8	29,7	35,1	16,2
Quality management	6,8	17,8	24,7	34,2	16,4
Resource management	6,8	20,3	27	33,8	12,2
Of communications	13,7	17,8	26	28,8	13,7
Knowledge management	10,8	12,2	20,3	33,8	23
Risk management	9,5	18,9	31,1	24,3	16,2
Procurement management	8,1	9,5	29,7	32,4	20,3
Management of the interested	10,9	8,2	24,7	31,5	24,7

Source: Authors' elaboration

Regarding the second level of maturity in project management, which is related to the measurement of processes, Table II summarizes the results obtained. When analyzing the processes with less measurement or use of metrics, the results of Table II, show that according to the perception of project managers, correspond to those related to selection, recruitment, income, training, and discharge of the members of the project team . In this same direction of the processes, with less implementation of metrics are those related to the management of project stakeholders and

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communication of the project and the processes related to the management of risks and opportunities of the project, which is worrisome. Regarding the processes with a greater degree of maturity regarding the use of metrics, the results show that they are those related to the schedule, budget, scope, and exchange control and contract administration. Again, the processes with the highest degree of maturity at the measurement level in the construction projects correspond to the iron triangle of the projects.

Table II. Maturity in process standardization

MEASUREMENT OF PROCESSES - USE OF METRICS	SPORADIC USE	LIMITED APPLICATION	IMPLEMENTED	CHECKED	OPTIMIZED
Clear and measurable objectives regarding time, cost and quality	1,4	14,9	29,7	36,5	17,6
Planning, fulfillment of goals, control of changes	4,1	12,2	28,4	36,5	18,9
Definition of activities, control of sequence of activities, duration of activities and costs associated with activities	8,1	12,2	25,7	37,8	16,2
Quality assurance	6,8	10,8	32,4	36,5	13,5
Acquisition of Personnel	5,4	18,9	35,1	29,7	10,8
Distribution of Information	5,4	16,2	35,1	31,1	12,2
Risk management	6,8	13,5	41,9	23	14,9
Contract Administration	6,8	10,8	31,1	41,9	9,5
Managing conflicts with stakeholder groups	4,1	13,5	25,7	36,5	20,3

Source: Authors' elaboration

Table III summarizes the results obtained from the perception of the construction project managers regarding the maturity in the control of the processes. Controlling processes implies a greater degree of maturity in the management of projects. The results of Table III, indicate that the processes with sporadic use or limited application of techniques and control tools, according to the perception of the study participants, corresponding to the management of the communications plan, risk management plan, and project opportunities and performance reporting . In contrast, the processes related to the area of knowledge of budget management are those that have implemented, controlled, or optimized control in construction projects in the Colombian context.

Table III. Maturity in process standardization

PROCESS CONTROL	SPORADIC USE	LIMITED APPLICATION	IMPLEMENTED	CHECKED	OPTIMIZED
To manage the stability of the Startup Processes, identification of needs, planning and development	4,1	13,5	35,1	23	24,3
To manage the stability of Integrated Change Control Processes	9,5	16,2	28,4	29,7	16,2
To manage the stability of the Processes for defining activities, sequencing activities, and estimating the Duration of Activities	4,1	17,6	25,7	39,2	13,5
To manage the stability of the Processes in terms of cost estimate and budget control	5,4	8,1	32,4	28,4	25,7
To manage the stability of Quality Assurance Processes	9,5	8,1	29,7	39,2	13,5
To manage the communication plan	9,6	11	31,5	28,8	19,2
To manage the stability of the Performance Report Processes	9,5	12,2	23	35,1	20,3
To manage the stability of the Risk Management Planning Processes	6,8	12,3	31,5	35,6	13,7
To capture, analyze and apply the lessons learned in the projects	5,4	10,8	25,7	35,1	23
To manage the stability of the Closing Processes	5,4	8,1	27	37,8	21,6

Source: Authors' elaboration

The highest maturity level of the project management processes corresponds to continuous improvement. Table IV presents the results of the perception of project managers against sporadic use, sporadic application, implementation, control, or optimization of continuous improvement in the management of construction projects. According to the results of table IV, the processes with less maturity at the level of continuous improvement correspond to those related to the project communications, integrated change control, and monitoring of customer satisfaction. Regarding the processes of project management perceived with a greater degree of continuous improvement, the results of Table IV indicate that they correspond again to those related to the area of knowledge of budget management and those that have to do with the administration and closing of the contract.

Table IV. Maturity in the continuous improvement of the processes

CONTINUOUS IMPROVEMENT OF PROCESSES - IDENTIFY, EVALUATE AND IMPLEMENT	SPORADIC USE	LIMITED APPLICATION	IMPLEMENTED	CHECKED	OPTIMIZED
Start, development and execution	8,2	9,6	31,5	35,6	15,1
Integrated Change Control	4,1	20,3	28,4	35,1	12,2
Definition and development of activity schedule and activity sequencing	6,8	18,9	33,8	33,8	6,8
Estimation and control of Costs, and budget	5,5	13,7	31,5	35,6	13,7
Planning and control of Quality	10,4	10,8	32,4	33,8	12,6
To achieve customer satisfaction	4,1	18,9	27	33,8	16,2
Communication Planning	6,8	14,9	28,4	35,1	14,9
Distribution of Information	5,5	19,2	21,9	38,4	15,1
Performance Report	4,1	17,6	24,3	43,2	10,8
Identification Planning and control of Risk Management	4,1	13,5	35,1	32,4	14,9
Planning and control of Acquisitions	4,1	13,5	31,1	40,5	10,8
Contract administration	4,1	13,7	32,9	27,4	21,9
Closing	2,7	13,7	32,9	34,2	16,4

Source: Authors' elaboration

Conclusions

In general, at all levels of maturity considered in this study, such as standardization, measurement, control, and continuous improvement of processes, according to the perception of the project managers, the basic orientation of project management in the construction sector towards the iron triangle of the projects can be evidenced, that is, towards the processes that make up the areas of management knowledge of integration, scope, schedule, budget, and quality. In general, at all levels of maturity considered in this study, the processes related to communication management, project risk management, and project resource management (especially human resources) are those of lower-level maturity. of standardization, measurement, control, and of course continuous improvement.

When focusing the analysis not on the processes of project management but the levels of maturity such as standardization, measurement, control, and continuous improvement, similar behavior is found in terms of the greater percentage of the participants who consider their processes to be found in the level of implementation. In this same order of idea, the percentage of project managers who consider that the use of techniques and tools in the processes is of sporadic use or limited application is lower than the percentage of project managers who consider optimized the use of techniques and project management tools in your processes.

The authors of this study wish to make explicit the limitations of the research to call for prudence when looking for generalizations of the results. In this sense, this study is cross-sectional, therefore, it is normal that the perceptions of construction project managers can change over time. Likewise, it is noteworthy that the present work was not based on the use of a methodology to measure the degree of maturity in the management of projects of an organization, but that it was sought to present the general perception of the maturity of project management of the construction sector, based on the particular perceptions of the project managers as to what they live on a day-to-day basis in the direction of the projects they are responsible

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for. In this order of ideas, this study did not consider the review of documentary evidence of projects to verify the answers to the questionnaire used for data collection.

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