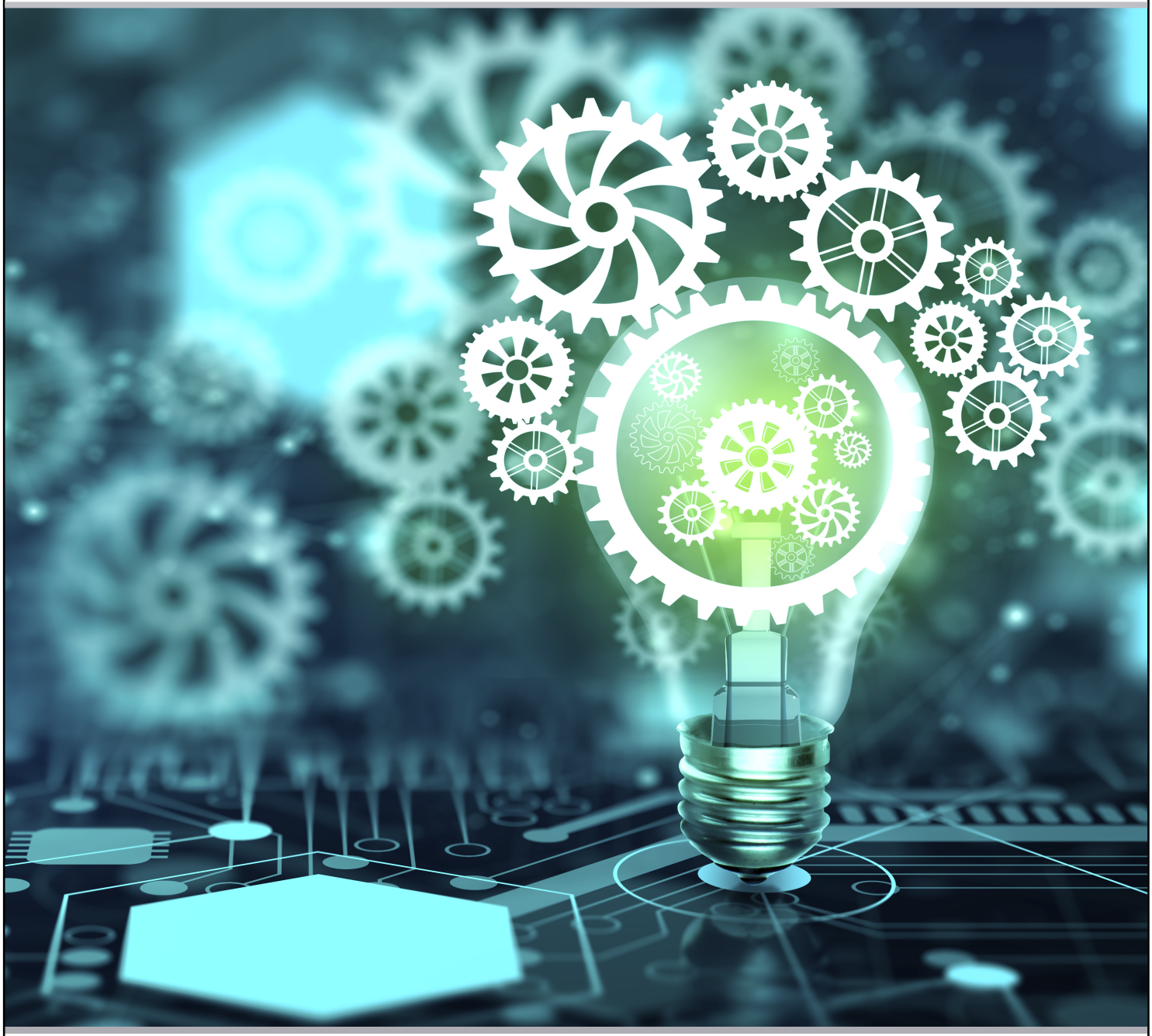
ISSN: 2683-1597

# Project Design and Management

January - June, 2022

VOL. 4 NUM. 1



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PROJECT, DESIGN & MANAGEMENT
Vol. 4 ● No. 1 ● Junio – June - Junho 2021
https://www.mlsjournals.com/Project-Design-Management

# EQUIPO EDITORIAL / EDITORIAL TEAM / EQUIPA EDITORIAL

# SUMARIO ● SUMMARY ● RESUMO

# Editorial

In this new issue, MLS Project Design & Management presents, once again, the joint work of our group of collaborators highlighting, as a primary tool, innovation in scientific-technological development. In the same way, it emphasizes the collaborative and integral work as a key piece in the development of cultural and social knowledge for the design of new projects. In this new edition, presenting 8 selected works, topics such as project management, the implementation of Information Systems for Management Indicators, and the use of MOOC (Massive Open Online Course) for training personnel of the Costa Rican Penitentiary System, also including topics on the use of GPS technology for real-time monitoring and control of cattle, tire recycling, and proper dosage of traditional materials for architectural restoration.

The first article presents a systematic review of the MACTOR method, an application for the analysis of human interactions that allows the identification of all the actors involved in a project, being of great importance for the management of development projects in the identification of their strengths and weaknesses. With the second article, through a quasi-experimental design and a longitudinal research cut, the effectiveness of implementing an Information System for the Monitoring of Management Indicators in the increase of sentences or final orders of the civil courts of the Superior Court of Justice of Tacna, during the year 2019, was determined.

The third article focuses on project management for large companies, focusing on the existence of a link between human resource management and SME project management. This work leaves an important line of research in the face of the questioning of the need to explore this research perspective. In the fourth article, a non-experimental, quantitative approach was used, where data from 349 university degree thesis projects in computer science degrees from two universities were analyzed, focusing on 3 management methodologies: Project Management Institute (PMI), a specific one for software projects, and the SCRUM framework.

Subsequently, in the fifth article, research work was conducted to determine and prioritize the training requirements of the Costa Rican Penitentiary System personnel, in order to analyze the feasibility of satisfying them through the use of MOOCs (Massive Open Online Courses). The study also included the identification of various platforms that offer MOOCs applicable to the satisfaction of the requirements of the personnel of the Costa Rican Penitentiary System. On the other hand, through the development of a prototype to determine the real-time location of cattle, the sixth article used a Global Positioning System based on GPS technology, requesting positioning coordinates from satellites. Undoubtedly, its importance lies in being able to track and control the animals in real time, thus combating theft and controlling their health.

Continuing with the seventh article, the growing rubber market available for recycling is analyzed with a cross-sectional descriptive design, using a real case of the Maule region in Chile and the statistical software SPSS, to identify, through a bibliographic search, the population of companies that generate tires. In this way, it was possible to consider a systemic model composed of inputs, processes, and outputs, not to mention the rules and resources that allowed establishing the discussion and conclusions of the work. Finally, in the last article of this issue, the use of traditional materials for restoration is established based on the mechanical behavior of the new dosages. The objective was to make a comparison between each of the mechanical tests in order to establish the best dosage to be used in an architectural restoration process.

Before concluding this editorial, it is important for all of us who collaborate in this new project to thank the team of collaborators, IT, and technical, in addition to the Ibero-American University Foundation (FUNIBER) and the Universities that have provided all the support

material so that this issue can be carried out, with the conviction that we are on the right path towards international recognition.

Dr. Luis A. Dzul López
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**PROJECT, DESIGN AND MANAGEMENT**

**ISSN: 2683-1597**

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

Assontia Djoudji, G., Kolokosso à Bediang, R. & Joël Begnikin, J. (2022). El método MACTOR para analizar los procesos de gestión de los proyectos y programas de desarrollo en África. *Project, Design and Management,4*(1), 7-19. doi: 10.35992/pdm.4vi1.835

# THE MACTOR METHOD FOR ANALYSING THE MANAGEMENT PROCESSES OF DEVELOPMENT PROJECTS AND PROGRAMS IN AFRICA

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**Abstract.** The proliferation of development projects in Africa in general and in Cameroon in particular over the last decade contrasts with their performance, which in most cases remains mixed. These performances depend to a large extent on the strategies and decisions taken by the interacting actors. Strategic analysis is therefore a fundamental approach to better understand the performance of development programs. The MACTOR method (Godet, 2007) fits into this framework; an application of actantial rationality in the analysis of human interactions. It makes it possible to identify all of the active and passive actors involved in a project and to define the matrix of alliances, conflicts, strategies, tactics, and objectives pursued by these actors. This method opens the way to an actancial analysis of the management of development projects in order to better identify their strengths and weaknesses. This article is a systematic review of the issues at stake in this method and its application in the Cameroonian context. It highlights the theoretical determinants of the method and its relevance in the managerial analysis of projects under an actantial rationality.

**Keywords:** MACTOR, actors, stakeholders, project, program.

# EL MÉTODO MACTOR PARA ANALIZAR LOS PROCESOS DE GESTIÓN DE LOS PROYECTOS Y PROGRAMAS DE DESARROLLO EN ÁFRICA

**Resumen.** La proliferación de proyectos de desarrollo en África en general y en Camerún en particular durante la última década contrasta con sus resultados que en la mayoría de los casos son ambiguos. Estas actuaciones dependen en gran medida de las estrategias y decisiones adoptadas por los actores que interactúan. El análisis estratégico es, por tanto, un enfoque fundamental para comprender mejor los resultados de los programas de desarrollo. En este marco encaja el método MACTOR (Godet, 2007), una aplicación de la racionalidad actancial en el análisis de las interacciones humanas. Permite identificar a todos los actores activos y pasivos que intervienen en un proyecto y definir la matriz de alianzas, conflictos, estrategias, tácticas y objetivos que persiguen estos actores. Este método abre la vía a un análisis activo de la gestión de los proyectos de desarrollo para identificar mejor sus puntos fuertes y débiles. Este artículo es una revisión sistemática de las cuestiones en juego en este método y su aplicación en el contexto camerunés. Destaca los determinantes teóricos del método y su relevancia en el análisis de gestión de proyectos bajo una racionalidad actancial.

**Palabras clave**: MACTOR, actores, partes interesadas, proyecto, programa.

## Introduction

Social change is a delicate and sensitive undertaking. In developing countries, social and economic change is a necessity to eradicate poverty and social inequality. To achieve this ideal, developing countries are jointly building economic and social programs to improve the living conditions of their populations. These countries are moving decisively towards a development planning perspective through projects and Rapid Winning Initiatives (IRRs). While these initiatives are commendable, the expected results are rather mixed. Various development programs are designed and implemented, but poverty persists and underdevelopment remains. Under these conditions, it is logical to assume that the problem lies not only in the rationality of development planning but, especially, in the interactions between the actors involved in these projects. To verify this hypothesis, it is necessary to mobilize simple and practical methods to evaluate the performance of development projects from a strategic perspective. This is where the MACTOR method comes into play.

The strategic analysis of organizations began with Michel Crozier and Erhard Friedberg in 1977. In their bestseller, *The Actor and the System,* the human being is seen as a rational actor who reasons, thinks, and acts opportunistically to satisfy his needs. He sets goals and applies strategies and means to achieve them. Following Crozier, Godet (2007) develops a more operational and appropriate approach to understand the strategies of passive and active actors involved in development projects. This approach, known as the *MACTOR* method (Method ACTors, Objectives, Power relations), is the subject of this study. It is a cross-cutting method applicable to all social and economic situations in which social actors interact. In this case, the context studied is that of the development project. It is a development project in which several direct and indirect stakeholders are involved and in which several development actors interact, playing different, complementary, or contradictory roles.

This paper reflects on the application of the MACTOR method in the context of development projects in developing countries. The objective is to highlight the relationship between strategic behavioural analysis and the performance of development projects.

Specifically, the aim is to demonstrate that the MACTOR method remains a suitable framework for the strategic and cognitive-behavioural analysis of actors involved in development projects, and it has important consequences for the performance of these projects. The article is therefore of interest to several scientific fields, such as project management, economic psychology, and organizational psychosociology. It has a triptych structure, developing in the first part the applicability of the method in the context of development projects, stating in the second part the specificities of the method and proposing in the third part perspectives on the method.

## Method

### *Data and data collection*

This reflection was made possible through data mining and access to documentary sources on several sites, in particular the Cahier du Laboratoire d'Investigation en Prévision, Stratégie et Organisation (Lipsor). Exploitation of databases or electronic platforms dedicated to research was not excluded: Cairn.info; JSTOR; ScienceDirect; Society and Business Review; Academy of Management Journal; Systems Research; érudit.org; googlescholar.com; African Journals OnLine (ajol.info); semantic Scholar; emerald insight.com; Journal of Management Studies; Research in Organizational Behaviour; RIMHE: Revue Interdisciplinaire Management, Homme & Entreprise; sites highlighting published doctoral theses were visited, such as thèse.fr, etc.

### *Applicability in the strategic analysis of development projects.*

A development project is a temporary economic initiative aimed at building infrastructure or correcting structural or social dysfunctions. In other words, a development project is a plan of action, an operational structure that mobilizes stakeholders to achieve development objectives. Thus, the development project is a work of strategic and operational planning. For its implementation, the project brings together different stakeholders and assigns them roles and performance objectives to be achieved. In addition to the project objectives, the co-actors have their own personal objectives, which are also discrete variables that affect the achievement of the project objectives.

Development projects involve various psychosocial and economic issues. The actors involved in projects play different roles, pursue specific objectives, and use financial, material, communicative, psychological resources, and means of action. The stakes involved in the implementation of development projects are very high. This gives rise to two types of interactions: on the one hand, conflictual interactions (antipathies, interpersonal, inter- and intra-group influences, threats, manipulations, etc.); and, on the other hand, interactions by accommodation (friendships, proximities, alliances, social ties, negotiations, etc.). These interactions will give rise to power relations between the actors involved in the achievement of the project's objectives. These actors, the main animators of the development project scenario, will influence in one way or another the achievement of the development objectives.

### *Specificities of the MACTOR method*

#### *Presentation of the method*

The "*actors' game"* method was developed in 1989-1990 by François Bourse and Michel Godet. The MACTOR method (Method ACTors, Objectives, Power relations) proposes an approach for analysing the set of actors and a series of tools that make it possible to take into account the richness and complexity of the information to be processed, providing the

analyst with intermediate results that shed light on certain dimensions of the problem in question. In other words, it is a matter of describing a system by means of a matrix of actors linking all the constituent elements of this system. From this description, this method aims to estimate the power relations between the actors and to study their convergence and divergence, with respect to a certain number of issues and associated objectives. The use of the method also makes it possible to understand the alliances and conflicts of a stakeholder ecosystem and provides an analysis of the likely outcomes of the issues at stake (consensual/dissensual objectives). But it also, if necessary, provides an actor with a decision-making aid for the implementation of its policy in interactions where alliance plays and likely conflicts linked to the implementation of its policy abound (Godet, 2004; Godet, 2008; Godet and Durance, 2011).

***The phases of the method***

Peerboccus (2021) proposes an iteration in seven successive steps as opposed to Godet's (2007) five:

1 - Building the stakeholder strategy framework

This table is used to represent each stakeholder's goals, objectives, problems, and means of action.

2 - Identifying strategic issues and associated objectives

The actors in the system pursue multiple and varied projects. The combination of interactions reveals a number of strategic issues on which the actors will have convergent or divergent objectives.

3 - Positioning of each stakeholder in relation to strategic objectives

The aim is to describe the current attitude of each stakeholder towards each objective.

4 - Prioritize the objectives of each stakeholder

The method proposes to specify the number of strategic objectives on which the stakeholders, taken in pairs, converge or diverge.

5 - Analyse the structure of direct and indirect influences between actors and calculate power relations.

MACTOR tools, which make it possible to highlight certain dimensions of the problem, must disappear: only collective intelligence and plural knowledge of the system can help to formulate strategic recommendations.

6 - Integrate power relations in the analysis of convergences and divergences between actors.

New graphs of possible convergences and divergences between all the actors are obtained. The comparison between the series of graphs allows us to observe the deformation of potential alliances and conflicts, taking into account the hierarchies of objectives and the power relations between the actors.

7 - Formulate strategic recommendations and key issues for the future.

Through this phase, MACTOR contributes to the formulation of key issues and strategic recommendations.

The method includes the software of the same name for the quantitative analysis of the data collected in the matrices. Besson (2010) identifies as another strong point, the applicability and operability of the method in companies that game theory most of the time leads to theoretical models that are not very obvious to use in everyday life.

Limitations must also be taken into account. The program requires a high level of analysis by the users. Without this analysis, an overly mechanical use of the software would mask the real problems and lead to misunderstandings. MACTOR presupposes a consistent behaviour of each actor in relation to its objectives, which reality sometimes belies. The same is true for information gathering, which requires relevance and consistency. However, according to software designers, applications are still limited by mathematical constraints and often restrictive assumptions. As another limitation, Besson (2010) points out that the quality of the results obtained depends on the relevance of the data entered at the beginning. Elements on the strategy of other actors are not always easy to obtain, so it will be necessary to cross-check a lot of information. This method assumes that the behaviour of each actor is in line with its objectives, which in reality is not always the case.

## ***Brief presentation of the actors of development projects in Africa***

This article will reflect on the role that MACTOR can play in facilitating the analysis of interpersonal interactions in the specific context of PPD. MACTOR will facilitate a broad presentation of stakeholders. There are multiple stakeholders in the PPD domain. However, in many cases, these stakeholders are both external and internal to PPD. A brief description of the activities of each of them allows for a more precise consideration of their roles in the construction of the PPD. These external (strategic) and internal (operational) stakeholders will play a key role in achieving PPD outcomes.

### *External or strategic stakeholders for PPDs*

Among the groups of external stakeholders identified, without being exhaustive, are the Technical and Financial Partners (TFP), key (strategic) stakeholders who accompany the State in the implementation of its development policy. They manage the State's authorizations, establish the management procedures for their projects and carry out monitoring and control and evaluation dissemination. In some cases, they provide technical assistance (TA). As such they are the main providers of international aid funds. They are also the main providers of international aid funds due to their historical links with the country.

Beneficiaries are the main targets, the object of much "greed", the raison d'être of the PDP. They are often consulted, but in most cases ignored. According to FAO (2005), the beneficiaries of a project are those who will benefit from its implementation, i.e. the public concerned. The literature identifies two types of beneficiaries, namely direct beneficiaries and indirect beneficiaries of specific and time-bound achievements of certain development objectives in principle within the logic of planned change.

Suppliers / Contractors of development projects are presented in the literature as legal entities or individuals that provide goods or services to the PPD (client). They are divided into several categories: wholesalers, service providers and subcontractors. The contractual relationships with the project are then established. The academic literature on the subject of management sheds light on the relationship between the supplier and the client.

Regulators: they will be so called because of their mission to ensure that project activities comply with or relate to current legislation. Their actions have a more or less important impact on the life of the PDP. Regulatory tools are represented by Laws, Decrees, Orders, etc. In addition, these strategic actors are mainly represented by the State through its

regional missions extended to the PPD. The institutions of the Cameroonian State are the actors who take the major strategic orientations and who finance them jointly or not according to the vision enacted.

Opinion makers (FOp) (international/media)**:** this group of actors consists of the specialized agencies (e.g. Moody's and S&P) that rate Cameroon's sovereign debt, which seems inevitable. The national press agencies. In this regard, according to the *EcoMatin* website*,* the financial rating agency Moody's *Investor Services* considers that Cameroon's credit profile could deteriorate further due to corruption, socio-political crises, and the absence of alternation at the top of the State, which makes it difficult for the country to meet its commitments.

In addition, the analyses produced by the FOp have a definite influence on the dynamics of international aid, given the credit given to them by the PTDs. Governments are also aware of the impact that the opinions of these FOp can have on the management of international aid. Their opinions are decisive in the monitoring and evaluation of projects financed by international aid. Moreover, their positions on Cameroon should not be overlooked. They appear as major players. International agencies such as *Reuters* and *Agence France Presse (AFP)* and those covering issues related to official development aid.

Opponents are represented by those whose PDP activities are contrary to their ambitions. These include some NGOs, a large part of the local communities who show a lack of trust in the promoters and decision-makers who consider them traitors to the community. In most cases, a balance of power is created, and the performance of the PPD depends on the distribution of power between supporters and opponents. One of the particularities of this group of actors is that they are also recruited from within the project. Their combined actions make them chiaroscuro actors and the orchestrated and sometimes permanent conflict situation makes them actors in search of social support.

As it is not possible to name all the external actors for the purposes of this research, despite their importance in the study of actors' strategies, the study has chosen to limit itself for reasons of format to the actors most directly involved in the system that constitutes PPDs in Cameroon.

*The internal or operational actors of the PPD*

Diallo and Thuillier (2005) identify and describe seven main project actors or "stakeholders," excluding subcontractors, design offices, and experts.

First, the coordinator is appointed by the government, usually the technical supervisory authority. Each project is headed by a project manager called the Coordinator. This is most often a civil servant, although a private sector official in this position is an exception. He is surrounded by a team of national staff. He sometimes plays the role of project manager.

A technical assistance team made up of national and/or international experts is often attached, depending on the type of contract. It is the backbone of the whole and responsible for the operational (technical) aspects of the project. The Project Management Team (PMT) or Project Management Unit (PMU) reports directly to the Coordinator who manages it with authority. Depending on the size of the project or program, the PMU is composed, with some exceptions, of the following key staff: a Monitoring and Evaluation Officer (MEO); an Infrastructure Officer (Rinfra); an Administrative and Financial Officer (RAF); a Procurement Officer; a Training Officer (RFO); an Environment and Sustainable Development Officer (REDD); in the case of PPDs, a Technical Officer (TO); an Internal Auditor (IA).

The project manager, task manager, or back stopper follows the PTD. He/she is located at the headquarters of the multilateral institution financing the project. He/she oversees the implementation of the project and ensures that the Bank's procedures are respected by the national project management or coordination unit (CNC). The Task Manager has implicit

power, which makes him/her the "cornerstone" of all SGPs in his/her portfolio. The latter definitely influences the dynamics of the project and the destinations of funds.

The line manager is usually a senior technical ministry official (supervisor); sometimes the minister himself or his representative, to whom the coordinator reports locally. Sometimes he/she acts as a liaison between the project and the technical supervisor.

The Steering Committee (COPIL) constitutes a sort of interface with the entire local institutional apparatus affected by the PPD. In other words, it is also the result of collaboration between the various administrations concerned. It is also often considered as the strategic body where the main orientations and budgetary constraints of the project are decided in a concerted manner, and where information and, above all, perspectives are updated and communicated. It is composed of designated representatives. In short, it is a decision-making structure, which is the relay of political will. It drives all stakeholders.

## Results and discussion of the MACTOR method: brief illustrations

Jaziri and Chérif, (2005) reviewed the progress of the contractualization project of Tunisian universities using the MACTOR method. The latter shed light on the conditions of success or failure of this project through the analysis of the games of the actors of the university system. This tool enabled Akanni-Honvo, et al, (2000) to envisage a set of possible futures for the African continent. A medium-term approach to African economies and societies based on the construction of relevant and coherent scenarios integrating the determinant games of the actors. Gatete and Dabat (2014), in a comparative institutional approach, question the development of agrofuels in some West African countries. They observe a craze around the activity but which poorly conceals the absence of clear and consensual strategies on the part of the development institutions (actors, stakeholders) of the countries involved. Between the promotion of sport, economic stakes, and political interests, Ben Mahmoud and Massiera (2014), aided by Michel Godet's tool, note that the governance of sporting events is "*trapped*" in the complex systems of actors, stakeholders, and collective stakes. Abdelkefi (2019) highlights the interactions between the main actors in the seed sector, their objectives, and their degree of achievement. Toledo Rojas (2014), for his part, uses the "*stakeholder relationships*" table of the MACTOR method to represent the relationships between innovation stakeholders and their weight. This same tool allowed, in 2007, Angélique Tholoniat to map and strategically analyse the actors' games when she was interested in territorial economic intelligence. To answer the question on the dynamics of actors, CIRIDD (2017) uses MACTOR to model the relationships between the actors of a project, to measure the weight of local actors in the realization of the Algiers nature reserve. Larid's (2010) reflection is based not only on the omission of the analysis of the relationships between the different partners involved in the management of the Algerian coastal territory, but also on the diffuse role of the decentralized structures of the State. He points out that this method of approaching the relationships between actors could lose reliability when applied to a long-term project. Gansaonre, Sodore, and Ouédraogo (2020) use the MACTOR tool to reveal the conflictive and uncoordinated nature of interventions in the W Park and its periphery. They note that this situation impedes the achievement of certain conservation objectives and the emergence of local initiatives. Mouhoubi and Sassi Boudemagh (2017) also used it with the aim of determining the responsibility of the actors in the failure of the project. They conclude that lack of involvement and inadequate monitoring of the participation of all actors at various levels influenced the success of the project (Mouhoubi & Sassi Boudemagh, 2017, p. 207).

The study conducted by Bouayad, Belhaj and Oucherrou, (2021) highlights the role and weight of strategic variables in the governance of sectoral policies in Morocco and the factors likely to reinforce their convergence. Plottu (2005) wonders whether it is necessary to harmonize the evaluation method in a democratic sense in order to bring public debate closer to rational decision-making. According to the author, this raises the problem of the choice of tools to facilitate decision-making. MACTOR is called upon to support stakeholder games in a participatory manner in relation to the issues and objectives of infrastructure projects. However, he recalls the advantages offered by this method. In particular, "the positioning of each stakeholder in relation to a set of associated objectives that can only facilitate the achievement of a negotiated solution." (Godet, 2004, pp. 80-85). Far from wanting to confront the logics of the stakeholders, the research proposes a paradigm for bringing public debate and rational decision-making closer together. Thus, participating in the evaluation of development projects would be an act of citizenship. Plottu and E. Plottu (2009, p. 43) would say that it is part of "the governance of public action and presupposes institutional conditions favourable to participation." Although this participatory approach does not seem to be the solution, it has the merit of mobilizing certain action verbs such as informing, motivating, and training in evaluation, for a consensual vision (B. Plottu & E. Plottu, 2009, p. 43).

Janin (2018) argues that we must think and act against hunger. His work warns of the danger of using Food and Nutrition Security (FNS) as a "power issue." (Janin, 2018, p. 1). Without taking sides, he reveals, based on the MACTOR method, that politics is perceived by FNS actors as a key to the failure of projects, but that its translation remains quite difficult (Janin, 2018, p. 4). In his research, Rakotobe (2018) identified three classes of stakeholders in the DomeTsip project. The author analyses the interaction of these stakeholders using MACTOR software to determine their positions and logics in the project area. He finds that each stakeholder uses the project objectives to his or her own advantage. To counteract this, he considered conducting a socioeconomic and ecological change study to facilitate decision-making and avoid altering the ecosystem. This method was used to identify key stakeholders in the context of security in northern and central Mali. It revealed the multiple facets of the actors involved in this conflict. It also allowed a better understanding of their influences on the evolution of the national, regional, or local security context and their interactions (O.P.H., 2018, p. 5).

Khattali, Sghaier, and Sandron (2018) convened the MACTOR method to understand stakeholder involvement in the local heritage conservation project. The study resulted in recommendations in the direction of consensus around the project purpose. A case study of twenty certified companies in the wilaya of Bejaia (Algeria) "addresses the games of alliances and power in the Quality Management System (QMS) by underlining the preponderant weight of each actor in the exercise of appropriation of the quality approach." (Meziani , 2018, pp. 133-134). Although there are divergences, the points of convergence remain sufficiently high to encourage the voluntary adhesion of the actors to the QMS.

Dockès et al. (2007) wanted to understand the changes underway and their consequences in a dynamic system such as agriculture. To do so, they borrowed from Michel Godet (2004) the MACTOR method and its software to answer the questions the authors wanted to ask themselves about the means of action or the power of the actors in relation to the different objectives and their respective positions (Dockès, et al., 2007, p. 14). After an iterative process, the authors estimate and position the farming profession in a liberal, controlled, and dynamic scenario, where the farmer is an important economic actor for the national economy. (Dockès, et al., 2007, p. 8). In 2015, Kanigui Yeo and Mohammed Benchekara studied localized agri-food systems (SYAL). The authors used the MACTOR and the *Attiéké* production system in Dabou to illustrate the trilogy between territory, agricultural activity, and agri-food products. In addition, to know and evaluate household accessibility to fish as a source

of protein; Kakpo A. (2014) uses MACTOR to analyse the structure of influences and stakeholder positions in relation to objectives. In particular, he questioned the most prominent conflicting objectives and the stakes of cooperation versus competition.

Jaziri and Boussaffa (2011), in examining the medical tourism project in Tunisia, identified its specificities. This work follows that of Jaziri and Miralam (2019), where the authors had identified the possibilities for the development of health tourism based on the analysis of its interactions, conflicts, cooperation, strategies, and objectives. The article provides an overview of the stagnation of Tunisian health tourism. Following the analysis, the authors considered that with MACTOR the framework for constructing the health field is more elaborated (Jaziri & Miralam, 2019, p. 147). With this in mind, Jaziri and Alnahdi (2019) made the sustainability of this new industry a concern. However, the work of Jaziri and Bousaffa (2007) pointed out that this field remains undeveloped as a research topic. The degree of success of the project was studied by analysing the interaction of the actors of the Saharawi "*tourism system*" in Tunisia. Strategic issues were revealed, which actors have convergent or divergent objectives. This work thus laid the groundwork for understanding the behaviour of the actors who, as stakeholders, condition the success or failure of the tourism development project (Jaziri & Bousaffa, 2007). In 2010, the same researchers questioned the responsibility of tourism stakeholders in relation to sustainable development. Charfi, Ghédira, and Kammoun (2015) note that the MACTOR approach has contributed to highlight two public actors with their objectives associated with the development of the cities of Sousse and Sfax. In the field of territorial management, using the same tool, Diemer (2020) used the coronavirus (COVID 19) to propose a territorial evolution model.

In the search for a solution to improve the irrigation system in the locality of Nadhour (Tunisia), political interference affects the performance of the collective management of irrigation water and its exploitation in the irrigated perimeters (Bennasasr & Bachta , 2018, p. 124). Governance was also the subject of the paper by Belfellah and Gassemi (2016). Their research led them to highlight a dual governance of the sector, composed of the administration represented by the ministry and the professional body. It is this interference that leads Kouassi (2018) to qualify the Ivorian state as an actor of disorder in the governance of protected areas. Taking the example of La Marahoué national park, the author places the State in the dock and, above all, confronts its responsibilities. Indeed, the author confirms the confusion and the turbulent game orchestrated by the representatives of the State, backed by its royal power, which seems to invade the governance of protected areas.

## Conclusion

A reflection built around a methodological issue such as MACTOR shows that the understanding of interactions depends on an effective decision support tool in overall performance management. Therefore, it is clear that, although the consensus is yet to be built, empirically, MACTOR in its transversality contributes to the construction of these elements. Basically, each author, both academic and professional, testifies to the effectiveness of the tool and the perception of the results obtained. In the specific case of PPDs in Cameroon, the MACTOR method will be a relevant contribution to observe and understand the games of the actors (stakeholders), their strategies, and organization in the development action and their performance. Beyond that, it helps to understand how stakeholders can participate in the field of societal development. A tool that provides timely, accurate, and ready-to-use information. It is therefore interesting to see to what extent the research can contribute to the decompartmentalization of stakeholder games, especially in development projects and programs in Africa.

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**Receipt date:** 09/30/2021
**Revision date:** 12/28/2021
**Acceptance date:** 01/03/2022

PROJECT, DESIGN AND MANAGEMENT

ISSN: 2683-1597

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

Flor Rodríguez, A. J., Arambarri, J., & Domingo Soriano, S. (2022). Egobierno: sistema de información para el seguimiento de indicadores y su incidencia en la producción judicial - caso Perú. *Project, Design and Management,4*(1), 20-35. doi: 10.35992/pdm.4vi1.980

# EGOVERNMENT: INFORMATION SYSTEM FOR THE MONITORING OF INDICATORS AND THEIR IMPACT ON JUDICIAL PRODUCTION - CASE OF PERU

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**Abstract**. The main objective was to determine the effectiveness of the implementation of the fan Information System for the Monitoring of Management Indicators in the increase of sentences or final orders of the civil courts of the Superior Court of Justice of Tacna - 2019. The type of research according to its function is quantitative, from a pre-experimental design with a quasi-experimental subcategory and a longitudinal research cut. All judicial files were taken in the civil courts during the 2018 and 2019 period in order to carry out the evaluation of the effectiveness of the Information System. For the construction of the solution proposal, a simplified methodology of the data extraction, transformation and loading process was used, and for the elaboration of the Information System, the Agile Unified Process methodology was applied. The main conclusion was that the implementation of an Information System for the Monitoring of Management Indicators as an e-Government measure, served to resolve the need for an increase in the issuance of Final Judgments and Orders, having at the end of the experimentation a 3% reduction in the time of qualification of the files, and despite the fact that the time in processing of the judicial files was increased by 4%, it was shown that the number of sentences and final orders had an increase of 165 in the Courts Civilians of the Superior Court of Justice of Tacna for the period 2019 compared to the period 2018.

**Keywords:** final orders, e-Government, management indicators, sentences, information system.

# EGOBIERNO: SISTEMA DE INFORMACIÓN PARA EL SEGUIMIENTO DE INDICADORES Y SU INCIDENCIA EN LA PRODUCCIÓN JUDICIAL - CASO PERÚ

**Resumen**. El objetivo general fue determinar la eficacia de la implementación de un Sistema de Información para el Seguimiento de Indicadores de Gestión en el incremento de sentencias o autos finales de los juzgados civiles de la Corte Superior de Justicia de Tacna – 2019. El tipo de investigación según su función es cuantitativo, desde un diseño preexperimental con subcategoría cuasiexperimental y un corte de investigación longitudinal. Se tomaron la totalidad de expedientes judiciales en los juzgados civiles durante el período 2018 y 2019 para poder llevar a cabo la evaluación de la eficacia del Sistema de Información. Para la construcción de la propuesta de solución se utilizó una metodología simplificada del proceso de extracción, transformación y carga de datos y para la elaboración del Sistema de Información se aplicó la metodología del Proceso Unificado Ágil. La conclusión principal fue que la implementación de un Sistema de Información para el Seguimiento de Indicadores de Gestión como una medida de e-Gobierno, sirvió para resolver la necesidad de incremento en la emisión de Sentencias y Autos Finales, teniendo al final de la experimentación una reducción de 3% en el tiempo de calificación de los expedientes, y a pesar de que se incrementó el tiempo en trámite de los expedientes judiciales en un 4%, se demostró que la cantidad de sentencias y autos finales tuvieron un incremento de 165 en los Juzgados Civiles de la Corte Superior de Justicia de Tacna para el período 2019 en comparación con el período 2018.

**Palabras clave:** autos finales, e-Gobierno, indicadores de gestión, sentencias, sistema de información.

## Introduction

Measurement or management indicators are used by the governing body of the Judicial Branch to establish management policies appropriate to the institution's mission; among the management indicators we have the production indicator, which is the most relevant for the budgetary support of this government sector.

Judicial Production is understood as the measurement of the procedural acts that end a judicial process in the first instance.

Now then, it is not possible to speak of judicial production without mentioning the procedural burden, which to (Flores, 2018) can be defined as a legal situation instituted in the law consisting of the requirement of a conduct of optional performance, normally established in the interest of the subject himself, and whose omission brings with it a burdensome consequence for him.

This procedural burden, according to (Alata, 2015) generates the delay of civil proceedings, leading to unnecessary delays in the procedural process. For the purposes of this research, it is also taken as a reference that a reform in the civil process is necessary (Alata, 2015), a reform in the Peruvian civil process is necessary, with new trends that can contribute to satisfactorily fulfill the purposes of the process for the solution of the conflict of interests and the elimination of legal uncertainties within a reasonable period of time.

The IT tools add value to the Judicial Office Management, which, for (Penadillo, 2019) presents a positive influence on the treatment of the Procedural Burden, in his study, objectively demonstrates that those offices with an efficient management of this presented a decrease in procedural burden; however, those that did not perform this work efficiently, presented a high procedural burden.

After an analysis of the problem, it is shown that the lack of interpretation of the information on the different control points in the processing of a case file causes a decrease in judicial production, together with the increase in the procedural burden that makes it impossible to track a case file in an adequate manner.

The aim is not only to implement an information system that allows to increase judicial production, but also to contribute to the increase of decisions on the merits in an optimized time, which translates into an increase in the number of judgments or final orders in the Civil Courts of the Superior Court of Justice of Tacna, in order to improve the service of administration of justice in this Judicial District.

Therefore, the development of a Software System for the Monitoring of Indicators is justified through the application of statistical data analysis techniques in order to have a positive impact on the increase of productivity, which will allow, as a consequence, to reduce the procedural burden.

The development of this project seeks to determine if the implementation of an Information System for the Monitoring of Indicators has a positive impact on the increase of the judicial production of the civil courts of the Superior Court of Justice of Tacna. In order to demonstrate it, we proceeded with the development and implementation based on the increase of the issuance of Judgments and Final Orders, which are part of the judicial production but which correspond to the identification of procedural acts that issue decisions on the merits of the conflict.

The information was obtained from the records of the Integrated Judicial System. These data were found immersed in four databases of records of procedural acts and statistical milestones; likewise, some records as an interpretation of instances or processes that could not be obtained directly, for which a methodology of simplified application of the process of extraction, transformation, and loading of data was followed; thus, agreeing with (Valero, 2016), which presents these data as a stepping stone to originate information which combined with the "know-how" is a source of knowledge and allows improving competitiveness.

As part of the methodology used, three phases were proposed for the ETL application: prerequisite phase, main phase, and an alternative phase.

For the construction of the Information System, the Agile Unified Process (AUP) was used, which was described by (Congacha & Noboa, 2019) as a version of the Rational Unified Process (RUP) in conjunction with the application of agile techniques, which allowed describing in a simple and easy way the stages and models of software development.

### *Background*

In his thesis entitled " Methodological proposal for the detention of Outliers in the statistical information system of the Judicial Branch of the Republic of Peru, 2013," he (Huamaní, 2016) proposes a methodology that allows detecting anomalous data in the registration of information in the Statistical Information System of the Judiciary of the Republic of Peru, in a scenario with production incentives (RA. N° 155-2012-P-P-PJ) as an alternative to the random methods used by decentralized control bodies. It is hypothesized that the optimal performance in the detection of contextual outliers depends on its treatment as a local and not global object depending on the degree of isolation, with respect to its closest neighborhood.

Using the local outlier factor technique, it is determined that for k=70 nearest neighbors, the detection model proposed reaches levels of 61.82% in precision and 97.72% in accuracy. This study served to obtain the approach for the detection of anomalous data in the information registry of the Integrated Judicial System by means of a local treatment of the data and not global, where we will try to demonstrate that the application of the proposed system will improve or serve as a catalyzing factor for the speed in the processing of judicial files.

We also took as a reference what was described by (Srikanta & Luan, 2017) in their article, who generally describe the concepts and applications of data analytics in the context of production for unconventional reservoirs. Topics discussed here under key concepts in data analytics include predictive modeling methods, missing variable handling model evaluation and validation, automatic model parameter fitting, and variable importance. Key features of a number of representative features are summarized and observations are made regarding the current state of practice with respect to limited model evaluation, restricted number of alternative models, ignoring data imputation, and omitting variable importance. Finally, some comments are presented on how the past may not be prologue for predictive model applications. The correlation of this study with this research lies in the application of the data analysis model for the application of techniques to analyze the information to be obtained from the general repository in order to standardize and improve the measurement of progress with respect to established productivity indicators.

***Definitions***

Judicial Branch of Peru: It is defined in (Judicial Branch of Peru, 2021) as a branch of the state that, in its functional exercise, is autonomous in political, administrative, economic, disciplinary, and independent in jurisdictional matters, subject to the Political Constitution of Peru.

No jurisdiction exists, nor can it be instituted, that can fulfill this same task, with the exception of military justice and arbitration bodies.

The Judicial Branch is, in accordance with the Constitution and the laws, the institution in charge of administering justice through its hierarchical bodies, which are the non-lettered Peace Courts, the lettered Peace Courts, the Superior Courts, and the Supreme Court of Justice of the Republic.

The operation of the Judicial Branch is governed by the Organic Law of the Judicial Branch, which establishes its organizational structure and specifies its functions.

This law defines the rights and duties of the magistrates, who are in charge of administering justice; of the parties, who are those who are being judged or who are requesting justice; and of the jurisdictional assistants, who are the persons in charge of providing support to the work of the members of the judiciary.

The Organic Law of the Judicial Branch currently in force originated in Supreme Decree No. 017-93-JUS, enacted on May 28, 1993 and published on June 2 of the same year. It consists of 304 articles, 1 Sole Complementary Provision and 33 Final and Transitory Provisions.

Productivity: According to (Seville, 2016), productivity can be defined as an economic measure that calculates how many goods and services have been produced for each factor used during a given period; likewise, it aims to measure the efficiency of production for each factor or resource used, i.e., the fewer resources or inputs used to

produce the same number of products, the greater the productivity and the greater the efficiency. This is usually represented by the formula:

$$\frac{Obtained\ production}{Amount\ of\ factor\ used} = Productivity$$

In agreement with the present article, and in agreement with (Sevilla, 2016), we can also define productivity as the relationship between results and the time it takes to achieve them. Time is often a good denominator, since it is a universal measure and beyond human control. The shorter the time it takes to achieve the desired result, the more productive the system is.

Production in the Judiciary: Productivity in the Judiciary is monitored by the National Commission of Judicial Productivity and to define the guidelines, Directive No. 013-2014-CE-PJ called "Integrated and Updated Guidelines for the Operation of the National and District Commissions of Judicial Productivity and the Office of Judicial Productivity" was made official by Administrative Resolution No. 419-2014-CE-PJ dated December 17, 2014.

This measurement is made by counting the number of judgments and final orders (i.e., the procedural acts that determine the solution of the dispute), measured by area, type of instance and spatiality, the latter is determined in Administrative Resolutions No. 174-2014-CE-PJ, 170-2016-CE-PJ, 186-2016-CE-PJ, recently modified in part by Administrative Resolution No. 395-2020-CE-PJ.

Of the documents mentioned above, only some items were modified, maintaining the form of measurement and, in some cases, even the measurement standard.

It should be established that, for the present study given that a study of the years 2018 and 2019 is made, in view of the implementation of this tool, what is indicated in Administrative Resolution No. 186-2016-CE-PJ will be taken.

Information System: A system is a set of components that interact with each other to achieve a common goal. Although there is a great variety of systems, most of them can be represented through a model formed by five basic blocks: input elements, output elements, transformation section, control mechanism and objectives. As shown in Figure 1, resources access the system through the input elements to be modified in the transformation section. This process is controlled by the control mechanism in order to achieve the set objective. Once the transformation has been carried out, the result leaves the system through the output elements.

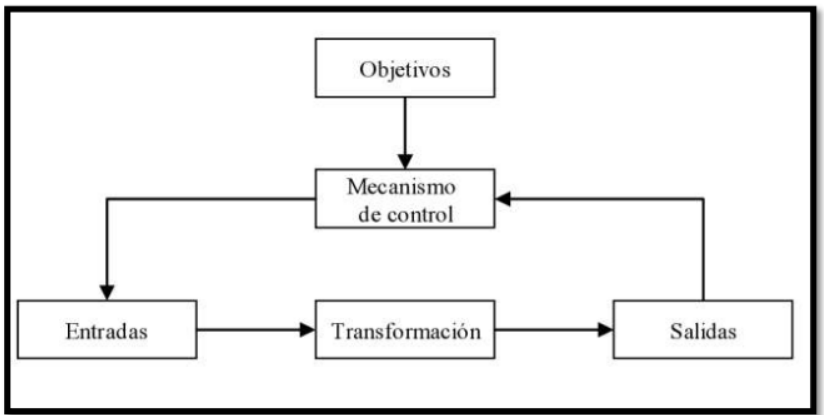

*Figure 1.* General Systems Model

*Note:* Source: (Fernandez, 2006)

Extraction, Transformation, and Loading Process (ETL): By means of the knowledge hierarchy, it is possible to relate data with information, knowledge, and wisdom. Figure 2 represents this hierarchy in which we can see how the different levels are related.

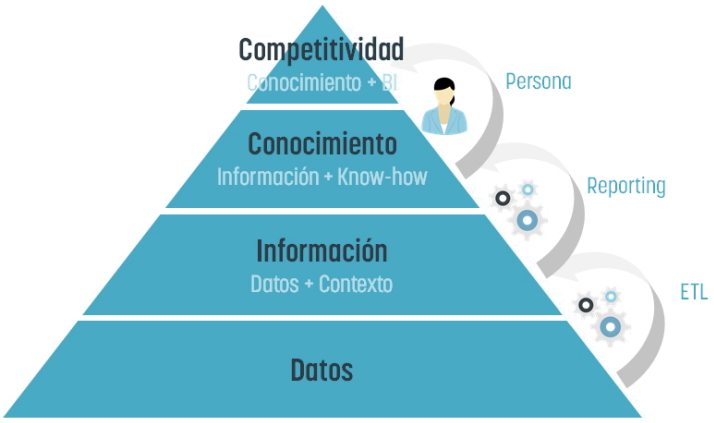


*Figure 2.* Knowledge Hierarchy

*Note:* Source: (Valero, 2016)

From the starting point, formed by the initial data set, the ETL processes that will give useful value to these data are developed, obtaining information from them. In the next step, the data, previously loaded in a repository designed for this purpose, are exploited by means of reporting tools, obtaining knowledge from them. Finally, and not always included in the knowledge hierarchy, we find wisdom, which consists of the ability to make decisions through the interpretation of the knowledge obtained through the generated reports.

To achieve this information, it is necessary to correctly design the corresponding ETL processes in each case. The following is a brief description of the process:

Extraction: This phase consists of obtaining data from the sources of origin. The data can have different origins, whether they are Relational Databases, Non-Relational Databases, files, etc.

Transformation: Consists of performing the necessary calculations. For example, if we have "number of clients" and "number of women" as a source, and we need to know the percentage of women who are clients, a calculation is needed to obtain the desired metric. If we need to adapt the format of a field for later exploitation, it would also be done here.

Loading: In this part of the process the data from the transformation phase are dumped into the target system. At this point, a direct dump can be made, keeping a storage history with the insertion date, or the data can be overwritten with the new information.


*Figure 3.* Example of an ETL Process

*Note:* Source: (Valero, 2016)

Agile Unified Process (AUP) Methodology: The Agile Unified Process (AUP) is a simplified version of the Rational Unified Process (RUP) developed by (Ambler, 2006). The AUP describes an approach to application development that combines concepts of the traditional unified process with agile techniques, with the objective of improving productivity.

In general, the Agile Unified Process is an intermediate approach between XP (Extreme Programming) and Rational's Unified Process, and has the advantage of being an agile process that explicitly includes activities and artifacts that most developers are already somewhat accustomed to. Many organizations are wary of XP because it seems too lightweight: XP does not specify how to create some of the artifacts that managers need, which is somewhat of a setback because XP is generally considered a good agile process.

The Agile Unified Process consists of four phases that the project goes through sequentially. These phases are, as in the Rational Unified Process, initiation, elaboration, construction, and transition.

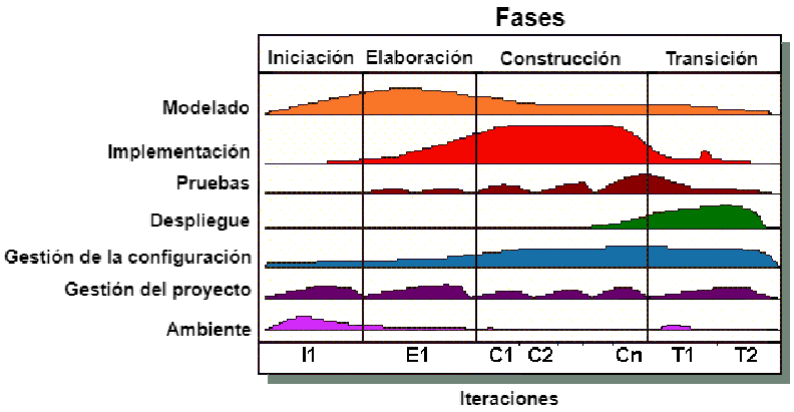


***Figure 4.*** **Phases and Disciplines of the AUP Development Methodology**

*Note:* Source: (Ambler, 2006)

It was decided to use the AUP (Agile Unified Process) methodology because of its simple and easy to understand approach to software development, using popular techniques and concepts that allow streamlining software development without compromising its quality. For this purpose, use case diagrams were generated and a definition of the requirements of the web application was made, as well as acceptance tests were applied to ensure its correct operation.

In addition, it is noted that this development methodology is consistent with Administrative Resolution No. 089-2019-CE-PJ, which formalizes Directive No. 002-2019-CE-PJ, called "Directive of Software Life Cycle Processes in the Judiciary," in accordance with "NTP-ISO/IEC 12207:2016-Software and Systems Engineering. Software Life Cycle Processes 3rd Edition."

***General Objective***

Determine the effectiveness of the implementation of an Information System for the Monitoring of Indicators in the Increase of sentences or final orders of the civil courts of the Superior Court of Justice of Tacna - 2019.

***Specific objectives***

Check whether the delay in the issuance of final orders is due to the lack of adequate follow-up of court files.

Demonstrate the effectiveness of the implementation of the Information System in terms of the increase in the issuance of Judgments and Final Orders in the judicial production of the Civil Courts of the Superior Court of Justice of Tacna.

## Method

***Data collection and analysis plan***

Since this work was carried out by subsequently evaluating the result of the implementation of the Information System for Indicator Tracking, the data collection for analysis was from the historical and obtained from the Information System at the end of the evaluated periods (2018 and 2019).

Likewise, the implementation of the Information System required the application of the process of data extraction, transformation, and loading, which were carried out twice a month during the 2019 period; for this, a process was established in conjunction with those responsible for the areas of statistics and the IT area of the Superior Court of Justice, in order to be able to make the statistical cuts and obtain the necessary data from the databases of the Integrated Judicial System.

The activities were carried out on a biweekly basis and were as follows:

Table 1
*Activities related to information gathering.*

| No. | ACTIVITY | DURATION | PERIODICITY |
|---|---|---|---|
| 1 | Statistical pre-closing | 35 min. | On the 15th of each month |
| 2 | Final monthly closing | 50 min. | On the 5th business day of each month |
| 3 | DB Query | 10 min. | At the end of each closure |
| 4 | Data consolidation and transformation | 25 min. | After each consultation |
| 5 | Data upload to the Information System | 10 min. | Finalizing the transformation |

*Note:* Source: Own elaboration.

These activities are repeated every month throughout the 2019 period, as they allow providing the necessary information to the Indicator Monitoring Information

System to fulfill its objective, it should be established that the implementation of this tool does not replace any of the tools already available to the Judiciary.

***Activities contained in the proposed practical solution***

For a better understanding and to set the development of this project, a context diagram of the solution is presented first, which will allow to focus on how the project was conceived for its implementation.


*Figure 5*. Context Diagram of the Proposed Solution

*Note:* Source: Own elaboration.

As can be seen from the Context Diagram, the activities are related to two processes, one of them is the extraction, transformation, and loading of data from the sources of the Integrated Judicial System (composed of 4 Databases), and the second process is the interpretation of the information obtained. In this second process, a list of inconsistencies and the procedural load reports will be obtained, which will be used for the tracking of files for their production.

For the ETL process, a model has been developed that, in addition to including the possibility of referencing different data sources, also proposed the detection and correction of inconsistencies, ensuring the integrity of the data that feed the repository of the proposed Information System.

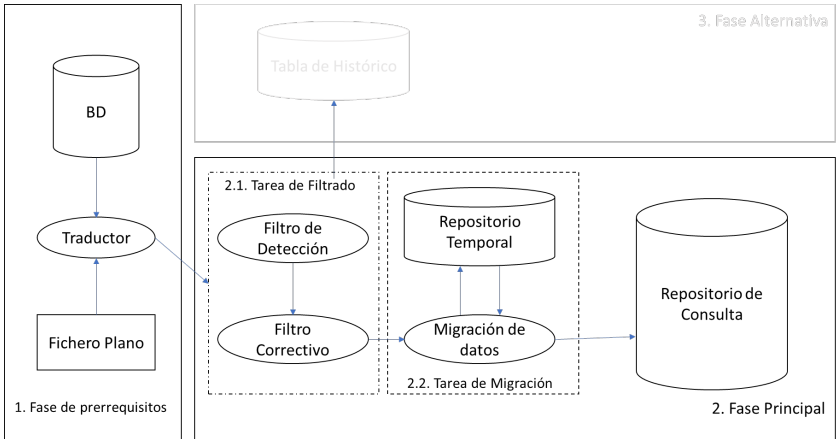


*Figure 6.* Proposed ETL model

*Note:* Source: Own elaboration.

Prerequisites Phase: The proposed model identifies different data sources, which can be flat files and structured data repositories (databases). These sources could present errors in their acquisition. Therefore, it is necessary to pass them through a previous process that has been called "Translator," which seeks to structure the data to present a standard form in the next phase.

Main Phase: The main phase consists of two processes or tasks, called Filtering Task and Migration Task, in which the structure obtained from the Translator process will be processed once again and, if necessary, the respective corrections will be made in order to proceed with the migration of the data to the Query Repository, which will be the data warehouse on which the Indicator Tracking Information System will act.

Alternative Phase: As an alternative phase, the activity of storing the history is proposed, which, as its name indicates, will store the information related to the errors, which could be the description, corrected value, position of the error, date, and time when the error was calculated.

In this phase, and alternatively, indicators related to the quality of the data to be transformed can be stored. These can be the Real Quality and Theoretical Quality of the data.

$$Real\ Quality = \frac{Total\ numberof\ valid\ records}{Total\ number\ of\ records}$$

$$Theoretical\ Quality = \frac{Total\ number\ of\ valid\ recors}{Theoretical\ measurement\ value}$$

The methodology for obtaining, transforming and loading data has been explained up to this point, but the methodology used specifically in the construction of the Indicator Monitoring Information System must also be specified, whose construction was based on the application of the AUP methodology, which consists of four phases: initiation, elaboration, development, and closure.

Iterations - consisting of each unit of time used for software development - were applied and lasted between one to four weeks. Each iteration of the development life cycle includes:

Initiation Phase: in this phase the external entities in which the system interacts (actors) are identified, and the purpose of this interaction is defined. It is achieved through the description of the system's use cases, resulting in an overview of the project requirements.

Elaboration Phase: here the project plan is elaborated and the strategies for the management of risks that may arise during implementation are established. It is necessary to have a holistic view of the system in order to define the functional and non-functional requirements of the system and its main stakeholders.

Development Phase: in which the characteristics of the system are developed, and the segments of the solution are integrated.

Transition Phase: in this phase, the corresponding tests are carried out and feedback is given to correct errors.

For the creation of the Information System, PHP and Javascript were used as programming language, it was built using the IDE Visual Studio Code and its database engine was PostgreSQL.

The Information System for the Monitoring of Management Indicators was deployed on a virtualized server, counting this deployment as another activity. It was configured with an Ubuntu Server 18.04 operating system, 4 Gb. of RAM memory and

two dedicated processors as well as a disk segment with 1 Tb of capacity, sufficient characteristics for the good performance of this system.

In order to run the application, we have an Apache 2 application server and a PostgreSQL 9.4 database engine. This being the detail of the deployment, we will proceed to the next part which is the operation of the system itself.

Once the data is transformed, it is loaded into the repository, so that the Information System can interpret the data, presenting a list of inconsistencies, which are those files that have errors in their history due to missing variables. The variables are used to track the files by stages.

These inconsistencies will help us so that those in charge of the jurisdictional bodies can correct them, either by adding or eliminating the variables entered, so that the ETL process can be carried out again to obtain consistent information and generate reports with a lower error rate.

Finally, after loading the data and processing it in the Information System, the necessary reports are obtained as follows:

| | N° expediente | Estado | Acto procesal | Mes - Año | Fecha registro | Tiempo transcurrido | Secretario | Juzg |
|---|---|---|---|---|---|---|---|---|
| 1 | 00003-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 11 - 2021 | 2021-11-02 | 26 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |
| 2 | 00005-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 5 - 2021 | 2021-05-18 | 6 meses 10 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |
| 3 | 00006-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 9 - 2021 | 2021-09-10 | 2 meses 18 dias | CABALLERO ROLDAN, MAXIMO - TRAMITE | |
| 4 | 00009-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 5 - 2021 | 2021-05-18 | 6 meses 10 dias | CABALLERO ROLDAN, MAXIMO - TRAMITE | |
| 5 | 00011-2021-0-2301-JR-CO-03 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 7 - 2021 | 2021-07-15 | 4 meses 13 dias | DIAZ PLATA, JESSICA ROXANA | |
| 6 | 00014-2021-0-2301-JR-CO-01 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 5 - 2021 | 2021-05-17 | 6 meses 11 dias | CABALLERO ROLDAN, MAXIMO - TRAMITE | |
| 7 | 00016-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 5 - 2021 | 2021-05-18 | 6 meses 10 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |
| 8 | 00022-2021-0-2301-JR-CO-04 | NUEVOS ADMITIDOS | AUTO: MANDATO DE EJECUCION | 11 - 2021 | 2021-11-17 | 11 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |
| 9 | 00024-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 5 - 2021 | 2021-05-18 | 6 meses 10 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |
| 10 | 00030-2021-0-2301-JR-CO-02 | NUEVOS ADMITIDOS | AUTO ADMISORIO | 8 - 2021 | 2021-08-05 | 3 meses 23 dias | RODRIGUEZ TANTA, JORGE - TRAMITE | |

*Figure 7.* Report of files for issuance of Final Order

*Note:* Source: Indicator Tracking Information System.

These reports show the data necessary to identify the file numbers, the status of the last procedural act, the date, the time elapsed, and the court clerk in charge of the file, sufficient data to determine the status of each file, and with this it is possible to request the file in order to generate the ex officio procedural acts to achieve the issuance of the final judgment or order that puts an end to the judicial process.

***Statistical analysis***

According to (Carrasco, 2019), the validity of an instrument means that it measures the variables of the study with objectivity, precision, veracity, and authenticity.

For this research, indicators related to the fulfillment of stages in the files were proposed, with an evaluation of the time it took to pass between each one of them, as well as an additional indicator that will make a direct comparison between the number of sentences and final orders issued in the periods to be compared.

For the descriptive analysis of the results, the tables with the results of the pre- and post-tests are shown. A detailed analysis of the data in each of the tables is presented below.

Table 2
*Statistical indicators of the research*

| Indicator | Pre-Test (Average) | Post-Test (Average) |
|---|---|---|
| KPI 1: Time in the qualification stage of a file | 26.72 days | 26.07 days |
| KPI 2: Time to issue final judgment or order | 171.13 days | 178.08 days |

*Note:* Source: Own elaboration.

From the study conducted, it is observed that indicator 1 related to the time in the qualification stage decreased from 26.72 days to 26.07 days due to the fact that the tool contributes to the tracking of files; likewise, indicator 2, time for issuing final judgments or orders, increased from 171.13 days to 178.08 days.

Table 3
*Comparison in the number of sentences / final orders, 2018 and 2019 periods*

| **JUDGMENT** | **FINAL JUDGMENTS/ORDERS 2018** | **FINAL JUDGMENTS/ORDERS 2019** |
|---|---|---|
| 1st Civil Court | 371 | 390 |
| 2nd Civil Court | 309 | 412 |
| 3rd Civil Court | 355 | 377 |
| 4th Civil Court | 335 | 356 |
| TOTAL | 1370 | 1535 |

*Note:* Source: Electronic Statistical Form

Finally, it is presented that, during the 2019 period in the civil courts of the Superior Court of Justice of Tacna, 1535 final decisions on the merits (Judgments and final orders) were recorded; this in comparison to the 2018 period, there is an undoubted increase.

## Results and discussion

After the application of the problem analysis and the solution proposal, we proceeded to the implementation of the Information System, which was developed in PHP language with a PostgreSQL database engine and deployed on a server of the institution.

Taking the data collected from the statistical analysis, we have that for indicator 1: Time in the stage of qualification of a file, there was a reduction in the time average, going from 26.72 days to 26.07 days, having a reduction per hours in the qualification on average.

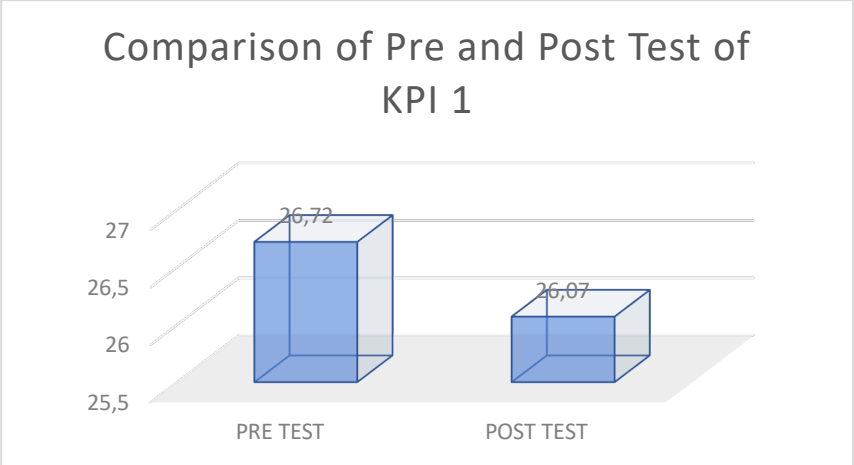


*Figure 8.* Average time to finish the Qualification stage of a file

*Note:* Source: Own elaboration.

The application of this tool, which, although its first conception is focused solely on increasing the number of sentences and final orders, has managed to boost the files from their initial stage, which is the qualification, in such a way that it generates a larger set of files in procedural load that after a well-managed process are ready for the issuance of a sentence.

The dispersion of the time elapsed for a file in the qualification stage in the pre-test was 136% and in the post-test 123%, which denotes a decrease in the dispersion, thus indicating the order in the qualification of files, a point that indirectly coincides with the object of implementation of the information system.

On the other hand, in the verification of indicator 2: Time to issue a sentence or final order, which measures the average time elapsed between the admission of a case to the processing stage, and its conclusion in the first instance (sentence or final order) was 171.13 days in the pre-test phase and 178.08 days in the post-test phase, which could be considered a negative result; however, this should be contrasted with the following indicator that measures the number of total sentences and final orders in both phases.

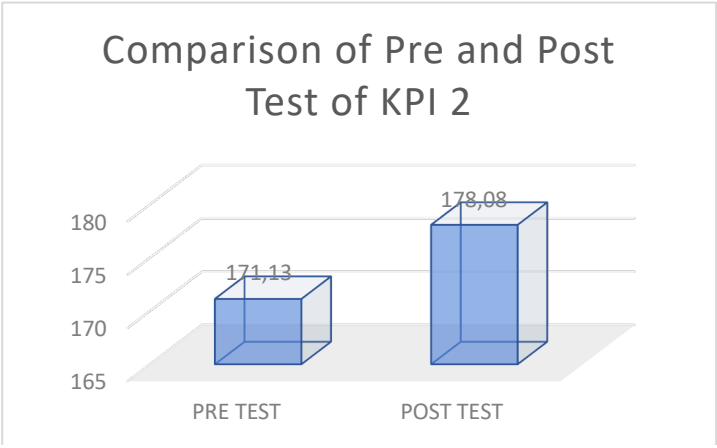


*Figure 9.* Comparison of the time a file spends in the processing stage.

*Note:* Source: Own elaboration.

It is necessary to review the dispersion of the data, which shows a decrease from 126% to 120%, thus providing a concordance that the application of the Information System for Monitoring Indicators allows an adequate flow of processing of judicial files.

To corroborate the result explained in indicator 2, the summary of indicator 3 is shown, which reviews the number of sentences and final orders issued in both the pre-test and post-test phases, previously shown in Table 3.

The number of sentences and final orders issued ranged from 1,370 in the pre-test phase to 1,535 in the post-test phase, in accordance with the dispersion indicators, which generate an increase in the number of sentences or final orders issued after tracking the files according to the consistency of the information and reports provided by the Information System for the Follow-up of Management Indicators.

From the results obtained in this study, which establishes that there is a positive relationship between the implementation of an information system for monitoring indicators and the increase in the issuance of judgments and final orders in the civil courts of the Superior Court of Justice of Tacna, in relation to what was stated by (Penadillo, 2019). This information system acts as a support tool in the management of judicial dispatch, and, as has been demonstrated, it has increased the issuance of sentences and final orders in the civil courts of the Court.

Along the same lines, we agree with (Neyra, 2015), who refers that the development of Information Technologies is necessary to contribute to transparency and improve the coverage and quality of attention to the justiciable. It is shown that this implementation is related not only to the increase of productivity, but it also translates into the maximization of attention with the same number of resources, thus increasing the quality of attention to the justiciable.

## Conclusions

This research allowed the implementation of an Information System for the Monitoring of Management Indicators as an e-Government measure, providing a solution to the problem of the low issuance of Judgments and Final Orders, having at the end of the experimentation a reduction of 3% in the qualification time of the files, and, although the processing time increased by 4%, it was shown that the number of judgments and final orders had an increase of 165 in the Civil Courts of the Superior Court of Justice of Tacna.

In this observation, it was determined that there is no way to track the files by stage, nor is there a measurement that compares the civil courts in the different stages of the judicial process; likewise, they do not know how much procedural load there is or what files could be available for the issuance of final judgments or orders if they are not in their possession.

It has been demonstrated that, with the use of the Information System for the Monitoring of Indicators, there has been an increase in the number of Judgments and Final Decisions, which are judicial resolutions that contain decisions of the judges on the merits of the process, thus increasing the production that solves the problems of the population. In this sense, it is concluded that this System has effectively achieved a positive impact on the Administration of Justice in the Civil Courts of the Superior Court of Justice.

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**Receipt date:** 12/17/2021
**Revision date:** 02/15/2022
**Acceptance date:** 04/21/2022

PROJECT, DESIGN AND MANAGEMENT

ISSN: 2683-1597

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

Youmbi, D. & Antoinette, S. (2022). Management of business projects in line with HRM: Impact of Human Resources Management practices on the Productivity of Cameroonian agri-food SMEs. *Project, Design and Management,4* (1), 36-51. doi: 10.35992/pdm.4vi1.936

# MANAGEMENT OF BUSINESS PROJECTS IN THE HRM AXIS: IMPACT OF HUMAN RESOURCE SATISFACTION PRACTICES ON THE PRODUCTIVITY OF CAMEROONIAN AGRI-FOOD SMES

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**Abstract:** Since project management is generally stressful because of its countless activities, a subjective HRM of projects leads to great conflicts and tensions. Previous scientific work has focused more on project management for large companies. The opinions of project management experts are divergent between those who are skeptical about its link with HRM and those who maintain that HRM is a global lever for project success. This study aims to enrich this debate by focusing on the existence of a link between HRM and the management of SME projects. The general hypothesis of the study is based on the principle that the HRM practices of SMEs can result in objectivity in recruitment procedures, the relevance of remuneration systems, rigors in training actions and the development of skills determine the levels of organizational productivity. The methodological design adopted is the wish-based sampling technique of administering a questionnaire to a sample of 87 parties interested in the study. The results reveal that HRM practices have significant links with the productivity of SMEs. These results could be explained by specific characteristics of HRM in SMEs. By way of discussion, since few studies are done in SME project management, shouldn't future methodologists give prominence to the exploration of this research perspective?

**Keywords:** Project Management, HRM, HR Satisfaction, Productivity, SME.

# GESTION DE PROYECTOS EMPRESARIALES EN EL EJE DE GESTION DE RECURSOS HUMANOS: IMPACTO DE LAS PRACTICAS DE SATISFACCION DE RECURSOS HUMANOS EN LA PRODUCTIVIDAD DE LAS PYMES AGROALIMENTARIAS CAMERUNESAS

**Resumen.** Dado que la gestión de proyectos es generalmente estresante debido a sus innumerables actividades, una gestión de recursos humanos subjetiva de los proyectos conduce a grandes conflictos y tensiones. El trabajo científico anterior se ha centrado más en la gestión de proyectos para grandes empresas. Las opiniones de los expertos en gestión de proyectos son divergentes entre quienes se muestran escépticos sobre su vínculo con HRM y quienes sostienen que HRM es una palanca global para el éxito del proyecto. Este estudio tiene como objetivo enriquecer este debate centrándose en la existencia de un vínculo entre la gestión de recursos humanos y la gestión de proyectos PYME. La hipótesis general del estudio se basa en el principio de que las prácticas de GRH de las PYMES pueden traducirse en objetividad en los procedimientos de contratación, la relevancia de los sistemas retributivos, los rigores en las acciones formativas y el desarrollo de habilidades determinan los niveles de productividad organizacional. El diseño metodológico adoptado es la técnica de muestreo basada en deseos de administrar un cuestionario a una muestra de 87 partes interesadas en el estudio. Los resultados revelan que las prácticas de gestión de recursos humanos tienen vínculos significativos con la productividad de las pymes. Estos resultados podrían explicarse por las características específicas de la gestión de recursos humanos en las pymes. A modo de discusión, dado que se realizan pocos estudios sobre la gestión de proyectos PYME, ¿no deberían los futuros metodólogos dar protagonismo a la exploración de esta perspectiva de investigación?

**Palabras clave :** gestión de proyectos, HRM, satisfacción de los recursos humanos, productividad, PYMES.

## Introduction

There is now consensus around the world that the strength of government economies is based on Small and Medium-Sized Agri-Food Enterprises (PMEA) (OECD, 2004). With this in mind, YASMINE (2019) notes that it is time for financial institutions and African government leaders to give a crucial place to the developments of these small agrifood industries. Indeed, PMEAs represent the backbone of the economies of the African continent in the sense that they employ more than 90% of companies and employ around 60% of the active population made up in particular of young people and women (FJOSE & GREEN , 2010). It should be noted that not only are the PMEA bases for the development and creation of new local jobs, they also make a substantial contribution to meeting urgent challenges which include in particular the provision of public services and sustainable development. In Cameroon, notwithstanding an enigmatic political and economic environment, PMEAs are considered to be catalysts of the national economy, occupying just over 90% of the fabric of production and 54% of job creation. NTOH (2009) points out that the relevance of PMEA is marked by the existence of a ministerial department dedicated to it, namely the Ministry of Small and Medium Enterprises, Social Economy, and Crafts (MINPMEESA).

Faced with a constantly changing business environment, SMEA entrepreneurs must take significant risks to overcome the many challenges they face (BEN, 2020). The innumerable challenges faced by many PMEAs favor their failures and often even their deaths. PMEA entrepreneurs fail because of traditional managerial paradigms not based on project modes. Some of the successful SMEA entrepreneurs make use of project-based management methods. Given that the management of PMEA in project mode refers jointly to a work strategy and a management technique, the objective of which would be to ensure cooperation and collaboration between several employees (Fleur, 2020). SMEA entrepreneurs must operate in project mode for several reasons. Among other things, this management method develops the degrees of trust, communication and cooperation between the stakeholders. This mode allows HR to get out of their ordinary operations to acquire new skills and consequently increase the various expected results upstream. Helping small and medium-sized enterprises to achieve the expected objectives would involve looking for professionals capable of project management (Brunet, 2021).

From economics to management, including new information and communication technologies, not to mention the agrifood industries, organizations must place project management at the center of their ambitions. Project management is the optimal approach to achieve strategic objectives in all structures (Granger, 2020; Goncalves, 2020). As such, project management occupies a prominent place in all organizations as a very effective management style (Granger, 2020). History tells us that project management appeared in its modern form at the dawn of the 1950s (Moperto, 2011). There are countless dimensions that characterize project management as an area of study. Among others, there is the management of civil engineering projects, the management of sanitary projects, the management of sustainable development projects and the management of enterprises. This scientific publication is positioned in the area of project management for companies focused on HRM. The choice of the HRM axis of PMEAs is not a risky fact even less reductionist, it is justified by the fact that PMEAs do not all conceive HRM in the same way.

In the SMEA ecosystem, a relevant HRM promotes the recruitment of high talents, contributes to the well-being of employees, guarantees the development of skills and above all builds the loyalty of high potentials. While PMEAs constitute the bulk of Cameroon's economic fabric and contribute better than large companies to the development of the country, Nkakleu (2016) considers that the review of the HRM literature of PMEAs is poorly structured. Within Cameroonian SMEAs, it is singular to realize that HRM is often reduced to the weak part of the iceberg, particularly in the administrative management of personnel (Revolution-Rh, 2016). As soon as we approach training, payroll, professional relations, recruitment and other practices in the field of social management, the HRM of PMEA shines with limits amply presented in the issue (Nabila, 2017).

The interest shown by the scientific community in the satisfaction of SMEA staff has grown over the past decade. Indeed, several researchers believe that staff satisfaction in SMEs is undoubtedly the concept studied by the greatest number of contemporary researchers (Larouche & Delorme, 1972; Lise, 1990; Surbhi, 2017). Notwithstanding this great scientific

deployment, methodologies do not seem to have access to in-depth knowledge of the satisfaction of the HR of SMEs (Larouche & Delorme, 1972). As of this date, no researcher knows whether staff satisfaction is an effective strategy promoting the HR involvement of SMEs in general, let alone agro-food SMEs in Cameroon. This is a limit and a lacuna relating to epistemology. In addition, there is no research that can confidently answer the following question: what are the effects of staff satisfaction on the productivity of agribusiness SMEs in Cameroon? Regardless of its status and size, the main asset of an SMEA is its human resource. It is right that for Peretti (2013), including the HR dimension in the strategy of any organization is now a necessity and pushes us to explore the theme entitled: "Impact of HR satisfaction on the involvement of Cameroonian SMEs. "

***Issue and Literature Review***

The development of African nations depends on the companies which are the engines of socioeconomic progress (Zambo, 2006). In the march towards the emergence of Cameroon by 2035, entrepreneurship through agri-food SMEs is decisive (Yang, 2009). Entrepreneurship in agri-food SMEs gives rise to questioning of personnel management methods in terms of job creation, both for modern companies and those under development (Garang, 1999). The concrete achievement of results in terms of job creation by agribusiness SMEs is proof of the improvement in the economic performance of nations (Amos, 2016). The Cameroonian head of government rightly declared: "The Cameroonian government relies mainly on the development of its SMEs to meet the immense challenge of employment" (Yang, 2009). It is singular to note the innumerable weaknesses of agribusiness SMEs (Patricia, 2005).

The weaknesses of agri-food SMEs are, among other things, the very high mortality rates, the lack of forward-looking skills management, the lack of interest on the part of managers for the well-being of employees (Axess, 2016). The lack of planning for agribusiness SMEs from their creation is a fashionable phenomenon for many owners (Mouyeme, 2010). The lack of interest in the health of employees of SMEs and the failure to take well-being at work into account in the management process of agro-food SMEs are evident in Cameroon (Axess, 2016; Clubdescho, 2018). Despite some efforts made by the managers of agribusiness SMEs to improve working conditions, the employees of these structures are still dissatisfied (Deschenes, 2018; ArunKumar, 2014). From executives to laborers through performers and agents, each socio-professional category in agri-food SMEs is the victim of the phenomena of dissatisfaction (Cambridge, 2020). The most recent CEGOS social climate study argues that employee satisfaction is lower in companies today (Colders, 2009).

The number of staff enrolled in agro-food SMEs is considerable. It represents a significant part of the proportion of the Cameroonian industrial fabric, i.e. around 50% (INS, 2016). Problems relating to the disengagement of this human capital are identified among the most prominent HRM concerns (Jim Clifton, 2012). Faced with this phenomenon of staff lack of commitment, most managers of agribusiness SMEs experience enormous difficulties in managing their staff in a sound and efficient manner (Balhadj, 2012). More and more, managers of agri-food SMEs are convinced that the achievement of results for their organizations inevitably derives from the quality of employee management (Peretti, 2011). However, in these

companies, the turnover rates are very high. This is a critical issue because staff turnover can slow down growth processes and induce loss of competitive advantage (Filev, 2017; Nwahanye, 2016).

Even if SMEs are important sources of income and tax contributions for nations around the world, Cameroonian agri-food SMEs suffer, more than large companies, from staff management problems by managers. From the observation of a sample of agri-food SMEs in the period 1996 to 2016, it appears that the inexperience and the lack of professionalism of the leaders precipitate the cessations of activity (Evou, 2020). Agrifood SME projects are not always well matured before they are set up (Mouyeme, 2010). The planning that should be done upstream of the actions turns out not to be a priority for the owners and managers of agri-food SMEs (Mouyeme, 2010). In fact, 80% of agri-food SMEs dies every five successive years (Yondeu, 2019).

Based on the aforementioned arguments, employees accuse the HR managers of PMEAs of doing nothing to ensure their professional future (Mouyeme, 2010). This study emphasizes the barriers of HRM that hinder productivity within Cameroonian PMEAs. The lack of professionalism in HRM leads to disinterest in occupational health and the disregard of skills in SMEs (Axess, 2016; Clubdescho, 2018).The central assumption of this scientific contribution was formulated as follows: the well-being of human resources determines their adherence to strategic and operational objectives. Its general objective was to verify from the opinions of the individuals surveyed whether HRM practices determine the levels of engagement within PMEAs.

Several researchers have devoted their scientific articles and doctoral theses to business management, and the number has continued to increase over the years (Vigan & Giauque, 2016). The theme relating to employee satisfaction is at the center of scientific production in business management and the countless research studies on this subject are irrefutable proof of this (Larouche & Delorme, 1972). Notwithstanding this popularity on staff satisfaction, it is strange to note that the results of studies are not yet unanimous among theorists (Larouche, Levesque, & Delorme, 1973). Below will be presented some studies with converging and divergent points of view.

In the article titled “What is Employee Satisfaction”, employee satisfaction according to Gutzman et al. (2020) is “the measures without which employees are satisfied with their work performance and their working environment” (p.1). Employee satisfaction is measured through a satisfaction survey. In this company survey, it is necessary to take into account the remuneration system, the costs of the activities of the employees, the expectations of the managers, the team work and the available resources (Gutzman, et al., 2020). Staff satisfaction can be a critical issue if it does not take into account the important values of top talent (Gutzman, et al., 2020; BasuMallick, 2020).

In the article entitled Happywork: Multi-Agent Modeling of Job Satisfaction, Chapuis and Kant (2014) focus on the subjective elaboration of job satisfaction and organizational influence. Chapuis and Kant (2014) focus on psychosociological models of employee

satisfaction in companies. The results of their research highlight the different properties and psychological approaches relating to the happiness of employees in companies. Added to this, the research reveals a business planning strategy determining employee satisfaction (Chapuis, 2016).

In his research work entitled Job Satisfaction of University Academics in China; YU (2009) is one of the few Chinese researchers to have looked into the topic of employee satisfaction. Yu (2009) takes a mixed approach combining qualitative and quantitative data collection. The study overcomes the literary vacuum while presenting the relationship between employee satisfaction and corporate culture. His results show that the job satisfaction of Chinese academics is correlated with several cultural factors.

In the article entitled Job satisfaction: a consequence of the choice of statistical tools and HRM measurement instruments, Iglesias et al. (2010) are interested in the link between employee satisfaction and statistical measurement instruments. Iglesias et al. (2010) note the subjectivities when measuring employee satisfaction. Job satisfaction according to IGLESIAS et al. (2010) is “a central concept in HRM. Despite this, the relationships found between this concept and other field variables are still sometimes uncertain or even contradictory "(p.245).

## Method

The empirical study itself was carried out during the period from January 2021 to March 2021. In this part, it is a question of presenting the operating framework of the research, the population and site of the study, the perspective of the study, the description of the data collection instrument, the data processing method and the statistical tools used.

Operational framework of the study: According to Law N ° 2010/001 of April 13, 2010 on the promotion of Cameroonian companies, it follows the existence of three SME models including in particular Very Small Enterprises (TPE), Small Enterprises (PE) and Medium Enterprises (ME). However, it seems appropriate to specify that the TPE is a structure employing more than five employees and therefore the share capital is less than fifteen million CFA francs net of tax. The PE is a structure whose number of employees is set between six (06) and twenty (20), whose annual share capital is included between fifteen (15) million FCFA and 100 million FCFA. The PMEA is an agrifood company which employs between 21 and 100 staff, whose share capital is less than one (01) billion FCFA (NATIONALE, 2010).

Study Population and Site: The study population viewed itself as the group of individuals with similar characteristics of interest to the research. She was represented by all of the nation’s SMEA stakeholders. In view of the multiplicity of Cameroonian PMEAs, it was opportune to collect data in the Adamawa region.

Study perspective: The sampling technique chosen made it possible to focus only on individuals with whom the data relating to the correlations between satisfaction practices and involvement in Cameroonian PMEAs are proven and palpable. So to access the sample, we opted for the wish-based sampling technique which consisted of interviewing 87 individuals (employees, entrepreneurs and SMEA sectors).

Description of the data collection instrument: In order to properly carry out the empirical investigations, a homogeneous questionnaire was designed, including closed items, of an impersonal and general nature, for the respondents. This questionnaire was completed by several sections including the identification of the respondents, the objectives and the project of the survey as well as the various questions. In order to ensure confidentiality, reduce frustrations and transcend respondents' suspicions, the mention of the name of the interviewee was optional. Following this identification grid, it was opportune through questions to assess whether the HR satisfaction of SMEas has an impact on the productivity of SMEas.

Data processing approach: To optimize the processing of data collected in the field, we made use of computer tools (laptops and electronic tablets). These tools made it possible to build a database and the research results were verified using the SPSS software (Statistics Packages of social sciences). The SPSS software facilitated the insertion of multiple tables and graphs. In addition, we also used Excel application software and a scientific calculator to check the percentages matches.

Inferential analysis: The inferential statistical tool that was chosen was the chi-square. It is also called chi-square, contingency Square, and Pearson's chi-square. Aware of the drawback of this method, which is the fact that it only indicates the existence of a link between the variables, but not the strength of the link between these variables, we nevertheless chose it for three reasons following: first of all it is used well with the nominal variables and also with the classes, then it manages to indicate the existence of a relation between two variables finally it applies whatever the distribution of the variables.

Statistical analysis with chi-square and degrees of freedom: The higher the chi-square, the greater the probability that there are relationships between the variables studied. To consult the tables, it was necessary to calculate the abbreviated degree of freedom in the form dof. In calculating the chi-square for a study variable, the degree of freedom was simply the number of categories minus one. In an array containing two variables, it is the product of the degree of freedom of each variable.

Methods used to test the four hypotheses: Let "V and V "be two quantitative variables (not necessarily having the same number of modalities, but represented in the same sample), It was possible to give a rigorous definition of the intuitive idea of independence between the variables. We had to formulate the hypothesis H0 according to which V and V "are effectively independent. The chi-square test was used to estimate the plausibility of this statement, given the frequencies observed for each pair of modalities in the sample. The results were interpreted in two distinct ways: Either by comparing the calculated chi-square value with that read in the statistical table, taking into account the degree of freedom. When the calculated chi-squares

were greater than the chi-square read in the statistical table, then the null hypothesis was rejected to consider the alternative hypothesis Ha. In this case, the null hypothesis was considered.

## Results

Q1: Are you satisfied with the ways in which human resources are managed in your organization?

Purpose of the question: This question is to analyse the satisfaction of employees with the human resource management within SMAEs.

Table 1
*On the satisfaction levels of employees with the HRM of their organizations*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 11 | 12.64 | 12.64 |
| No | 76 | 87.36 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

From this table, it appears that within Cameroonian SMAEs, 12.64% against 87.36% of employees surveyed are satisfied with HRM practices.

Q2: Do you think that recruitment approaches as practiced in SMAES are based on applicants' skills?

Purpose of the question: To test the relevance and objectivity of candidates' recruitment techniques.

Table 2
*On the perception of stakeholders' opinions on recruitment processes*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 19 | 21.84 | 21.84 |
| No | 68 | 78.16 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

21.84% versus 78.16% felt that the recruitment techniques adopted by SMAEs managers were not objective in the sense that they were not based on the skills of the job seekers.

Q3: Do you think that current recruitment techniques help HR productivity in SMAEs?

Objective of the question: To evaluate the effects of recruitment strategies on profitability levels in SMAES.

Table 3
*On the perception of respondents' opinions on the correlations between profitability policies and employee productivity*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 9 | 89.65 | 10.34 |
| No | 78 | 10.35 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data.

89.65% versus 10.35% of respondents recognize the existence of links between recruitment practices in companies and employee productivity levels.

Q4: Are you satisfied with your company's compensation systems?

Question objective: To assess HR satisfaction with compensation policies.

Table 4
*Employee views on levels of satisfaction with compensation policies*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 29 | 33.33 | 33.33 |
| No | 58 | 66.66 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

33.33% versus 66.66% of the respondents find the remuneration strategies implemented in the SMAEs to be ineffective in contributing to human capital satisfaction.

Q5: In your opinion, can objective compensation policies practiced within SMAEs increase HR productivity levels?

Question objective: To assess HR satisfaction with compensation policies.

Table 5
*On the perception of respondents' views on the correlations between compensation systems and employee productivity*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 33 | 62.07 | 33.93 |
| No | 54 | 37.93 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

62.07% versus 37.93% maintain that the qualities of remuneration systems determine the performance of HR in Cameroonian SMAEs.

Q6: What do you think about training policies in SMAES?

Objective of the question: To identify the views of HR regarding their employers' obligations to provide retraining.

Table 6
*Respondents' opinions on the effects of employee training on their work performance*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 13 | 14.94 | 14.94 |
| No | 74 | 85.06 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

Only 14.94 vs. 85.06 of employees believe that personal development activities carried out in SMAES are beneficial.

Q7: In your opinion, does the ongoing training provided to employees have an impact on their job performance levels?

Objective: We would like to know if the training offered by companies to HR influences the engagement of HR in the workplace.

Table 7
*On the perception of respondents' opinions on the correlations between vocational training systems and employee productivity*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 52 | 59.77 | 59.77 |
| No | 35 | 40.22 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data

59.77% vs. 40.22% of SMAEs employees believe that continuous training determines their performance.

Q8: Are you satisfied with your company's ergonomic system?

Purpose of the question: To assess employee satisfaction with the ergonomic management of their workstations.

Table 8
*On the perception of the respondents' opinions on HR satisfaction related to ergonomics at work*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 17 | 19.54 | 19.54 |
| No | 70 | 80.46 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data.

Just 19.54% versus 80.46% of employees think their working conditions are good.

Q9: Does the ergonomic management of your company determine your productivity at work?

Objective of the question: To evaluate the correlations between ergonomic management in SMEs and employee productivity.

Table 9
*On the perception of the respondents' opinions on HR satisfaction related to ergonomics at work*

| | Frequencies | Percentages | Cumulative percentages |
|---|---|---|---|
| Yes | 50 | 54.47 | 54.47 |
| No | 37 | 42.53 | 100.00 |
| Total | 87 | 100.00 | |

*Note:* Source: Authors based on survey data.

With 54.47% of employees against 42.53%, ergonomic systems influence productivity in SMAEs.

Table 10
*Savings in hypothesis testing*

| HR | DOF | A | Coefficients Contingencies | $X^2$ Cal | $X^2$ Lu | Decisions |
|---|---|---|---|---|---|---|
| HR1 | 4 | 0.05 (5%) | 0.30 | 11.0211 | 8.388 | $X^2Cal>X^2Lu$ Conclusion Accepted $H_a$ |
| HR2 | 4 | 0.05 (5%) | 0.450 | 29.5233 | 8.388 | $X^2Cal>X^2Lu$ Conclusion Accepted $H_a$ |
| HR3 | 4 | 0.05 (5%) | 0.591 | 61.8820 | 8.388 | $X^2Cal>X^2Lu$ Conclusion Accepted $H_a$ |

*Note:* Source: Authors based on survey data.

The contingency coefficients are higher than 0.50 on the one hand and the observed Chi-square are all higher than the theoretical ones on the other hand, which suggests a dependency link between the variables of HRM practices (1), recruitment process, (2) remuneration systems, (3) continuous HR training, (4) remuneration systems and HR productivity. In conclusion, the results obtained validate the hypothesis that HRM practices determine work productivity in Cameroonian SMEs.

## Discussion

This study produced results that align with several methodologies who have focused on HRM practices in SMAEs, including Boogaard (2019), Balhad (2012), Boubakary (2020), Garang (1999). These famous authors believe that employee dissatisfactions are the main causes of low productivity in SMEs. According to research of the direction of animation, research, studies and statistics (DARES) of the French government held in 2016, it follows that the lack of recognition or even dissatisfaction at work triples the risks of occupational diseases and doubles that of depressive states in HR. Conversely, the power of HR satisfaction is high. For Christine (2019), employee dissatisfaction has a direct effect on absenteeism, conflict, commitment and productivity in SMEs.

Employee satisfaction is a key factor in the strategic management of human resources. However, in terms of satisfaction, Granger (2021) believes that the human being is complex. It is up to the manager to find the elements that will guarantee the satisfaction of its employees. In this perspective, Herzberg proposes avenues of reflection in his theory of factors. Factor theory argues that any satisfaction practice is based on optimal motivation derived from two types of factors, including psychological and hygienic factors. Psychological factors are specific to each individual because they correspond to the well-being of employees, and are sources of satisfaction if the employee does not experience any parallel source of dissatisfaction. Hygiene factors are also specific to each person and refer to the working conditions. They can cause discontent and dissatisfaction at work.

For Hellriegel (2002), job satisfaction is a favourable emotional state that can result from the favourable impression one gets from one's professional performance. Cambridge (2020) and Clubdescho (2018) believe that it is appropriate to think that an employee who is satisfied with his or her job would in turn be able to meet the obligations and requirements of his or her job. In SMAEs, satisfaction occurs when the work performance is adequate to the employees' values and needs. Satisfied employees attract many customers. They will be positive and will, for example, promote an image of the SMAE that is consistent with their state of mind. Thus, they will attract new customers more easily and comfortably unlike dissatisfied employees characterized by a lot of animosity towards their structures.

In sum, it must be admitted that employee satisfaction is indispensable and necessary as a sine et quanum condition for increasing the degree of productivity at work. The SMAEs, although being levers of the nation's wealth, do not always function perfectly because of the phenomena of dissatisfaction of human resources. We believe that the entrepreneurs of SMAE deserve to be involved in the updating of human resources management methods. Among other things, we propose the following actions within the SMAEs: implement relevant HR recruitment policies, implement performance-based compensation systems. develop HR skills through training activities and adapting human resources to their workstations through ergonomic policies.

Notwithstanding the fact that one of the main consequences of employee dissatisfaction in SMAEs is the lack of productivity at work (Colders, 2009). Hope is not lost. It would be advisable to set up steering committees in order to devise HRM practices and mechanisms aimed at increasing HR satisfaction levels. In addition to the analyses listed above, this research has provided clarification on the relationship between HRM and project management, which to date has been the subject of several divergences. The management of SMAE in project mode is based on the development of employees and especially their job satisfaction. It should be noted that the economy we present in this study is clearly partial, if it is true that the expected objective upstream consisted of identifying only significant points. Other studies could complete this proposal by exploring the benefits that employee motivation could have on commitment to a company.

## Conclusion

The new economy of knowledge-based management of business projects has drastically changed the contours of management in global work platforms. Paradigms formerly based on technical or financial capital are gradually giving way to managerial dynamics that focus on intangible investment and the enhancement of HR as a driving factor in the dynamics of innovation and creation. The new managerial practices within SMAEs are signals the reposition

of HR to its true perspective and value by moving away from Taylorian approaches that reduced them to simple automatons. We believe that the employees within SMAEs as human capital must be preserved and nurtured. The stocks of skills they hold make them fundamental elements of development strategy better to improve the performance of SMEs in Cameroon, this with a view to enabling them to achieve the expected objectives, adequately carry out their missions and ensure their survival.

Having positioned HR in its real place in SMEs, it is now appropriate to present the economics of our research which focused on the analysis of HRM practices and their effects on workplace productivity. The research question was whether HRM systems implemented in Cameroonian SMEs influence productivity in the workplace. To this question, the main hypothesis that HRM practices significantly determine employee productivity was put forward. Four subsidiary hypotheses were retained. The results obtained supported these different hypotheses chosen upstream. To prove the truth of these hypotheses, it was necessary to carry out investigations by administering questionnaires to the interested parties, i.e., the employees, employers, and consultants of SMAEs.

The various results were presented in graphs and tables using computerized data processing tools. To determine the validity, reliability, scientificity and fidelity of the results of this research, we used tools that facilitated the computerized verification of the research hypotheses through chi-square tests. At the end of the different stages and the results obtained, we concluded that the independent variable of the theme namely "HRM practices" significantly improves the dependent variable in this case "the productivity of HR of Cameroonian agri-food SMEs". This means that the originality of our research would be reflected in the fact that it is management of business projects in the axis of HRM of SMEs in Cameroon Agribusiness on the one hand and it proposes avenues of solutions related to the low productivity of HR within SMEs. At the end of this study, it should be noted that the problem of productivity of Cameroonian agri-food SMEs can be resolved by improving employee satisfaction.

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**Receipt date:** 18/11/2021
**Revision date:** 25/01/2022
**Acceptance date:** 27/02/2022

PROJECT, DESIGN AND MANAGEMENT

ISSN: 2683-1597

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

Rojas Sánchez, M. Á. & Uc Rios, C. E. (2022). Gestión de proyectos en tesis de titulación universitaria. *Project, Design and Management,4*(1), 52-68. doi: 10.35992/pdm.4vi1.974

# PROJECT MANAGEMENT IN UNIVERSITY CAPSTONE PROJECTS

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**Abstract**. Project management is a discipline that directly influences the success or failure of any project, and the software industry is no exception. The university's academic curriculums focus on providing students the required knowledge to obtain technical and methodological skills that are necessary to achieve correct project execution. However, the emphasis on project management subjects, as well as their practice in real projects presents an additional difficulty and therefore a lower dedication than the rest of the knowledge areas. This article answers the following research questions: (i) How many hours do students devote to project management? and (ii) Are the project management hours related to the methodology applied? In this research work, descriptive statistics were used with a quantitative approach of a non-experimental nature, where data from 349 university capstone projects of computer science careers from two different universities were analyzed. The projects analyzed focus on 3 management methodologies: the one proposed by the Project Management Institute (PMI), one specific to software projects, and the SCRUM framework. Finally, depending on the results obtained, it is shown that in the academic context there are no considerable differences that relate the effort to the methodology applied and that the effort in management tasks is located in the range between 5% to 15 %, being consistent with the literature presented.

**Keywords:** project management, degree thesis, software development, comparison of effort between management methodologies

# GESTIÓN DE PROYECTOS EN TESIS DE TITULACIÓN UNIVERSITARIA

**Resumen**. La gestión de proyectos es una disciplina que influye en forma directa en el éxito o fracaso de cualquier proyecto y la industria del software no es la excepción. La curricula académica de las universidades se centra en brindar los conocimientos necesarios para que los estudiantes adquieran las competencias técnicas y metodológicas necesarias para lograr la correcta ejecución de un proyecto. Sin embargo, el énfasis en materias de gestión, así como la práctica en proyectos reales presenta una dificultad adicional y por consiguiente una dedicación menor que el resto de las áreas de conocimiento. En este artículo se responde las siguientes preguntas de investigación: i) ¿Cuántas horas se dedican los estudiantes

a la gestión de proyectos? y ii) ¿Las horas de gestión de proyectos se relacionan con la metodología aplicada? Este trabajo de investigación utiliza la estadística descriptiva con un enfoque cuantitativo de carácter no experimental, donde se analizaron los datos provenientes de 349 proyectos de tesis de titulación universitaria de carreras de ciencias de la computación provenientes de dos universidades. Los proyectos analizados se centran en 3 metodologías de gestión: la propuesta por el Project Management Institute (PMI), una específica para proyectos de software y el framework SCRUM. Finalmente, en función de los resultados obtenidos se demuestra que en el contexto académico no existen diferencias considerables que relacionen el esfuerzo con la metodología aplicada y que el esfuerzo en tareas de gestión se ubica en el intervalo de entre 5% y 15% siendo consistente con la literatura presentada.

**Palabras clave:** gestión de proyectos**,** tesis de grado, desarrollo de software, comparación de esfuerzo entre metodologías de gestión

## Introduction

According to the Project Management Institute (2017), a project is "a temporary effort that is carried out to create a product, service, or unique result" (Project Management Institute, 2017, p.4) due to the fact that a project requires the investment of material, economic, human, and time resources, among others, a previous step must be carried out to determine its feasibility.

Once the feasibility of a project has been determined, the next logical step is to carry out its planning. For Campo Arranz et al. (2014), the planning of a project consists of determining and estimating the activities, assigning the resources that will carry them forward and defining how the management and administration will be carried out.

The planning of a project is the initial step in the construction of a software system and it is in this planning where the different phases that compose it are defined, where in each phase different tasks are performed. However, there is a process that must be executed transversally and throughout the whole project, which is called project management. Project management is the activity in charge of verifying that the development of the project is carried out within the agreed deadlines, with the agreed quality and at the stipulated cost. The success of a project depends to a large extent on the correct execution of project management. (Sommerville, 2011).

In the industry, there is a large amount of information generated by companies, product of years of work, and accumulated experience. The collection of metrics on the effort dedicated to different types of tasks, hours invested, technologies used, as well as other types of information is a very valuable asset and is one of the innate activities of companies seeking to improve the execution of current projects and the planning of new projects.

Unfortunately, this information is held by companies and is hardly shared with academia. Cooperation between industry and academia through the exchange of information would make it possible to align academic plans with what industry needs. Sharing this information with academia is only possible if companies visualize the benefit or gain, not necessarily economic, that they can obtain either in the short or long term; in other words, a win-win investment in the future. The existing disconnection between academia and industry means that students do not have reliable information on real projects, and access to metrics or statistics of this kind of projects (real and current) is very difficult.

In the academic degree theses analyzed in this paper, students must perform the complete cycle of building an information system. This means that they must not only

demonstrate that they are able to build a system, but also that they are able to perform the project management activities. Within these activities, they must be able to perform estimation, collect metrics that feed back into the project, monitoring, risk management, and many other activities that will lead the project to a successful conclusion.

As expressed by Ramos Cerdas (2015), the role of the university does not consist exclusively in disseminating knowledge, nor in preserving acquired knowledge, since both actions can also be achieved by using a book. The role of universities is to keep knowledge alive, the conjunction between those who know and those who want to learn.

For Morales Vallejo (2013), academic goals are related to the students' learning process and the final grades they obtain. To help students meet academic goals, universities need to measure the degree and quality in which their students achieve their academic objectives as well as their learning. It is of vital importance for universities to detect those points that can and should be improved, allowing them to design academic strategies that allow them to reinforce those skills that do not present the expected quality or those skills that are not applied, and, thus, act upon them. Through these strategies, universities seek to train better professionals and citizens, which is the main and most important objective of a university.

The Association for Computing Machinery (ACM) publishes since 1960 recommendations for academic curricula in different computer science majors, where project management is included as a discipline that students must master. (Association for Computing Machinery, 2021).

For Fioravanti et al. (2018), software project management is one of the most relevant topics within software engineering, and it is for this reason that it should not be missing in the academic curriculum of computer science. The main argument put forward by this author is the relationship between project management and project success or failure. In this same line, he states that there are difficulties in linking theory with practice, and that teachers are not able to demonstrate the importance and relate these two realities. In the development of his article, he introduces and presents evidence of his experience applying project-based learning where students can apply their knowledge in real projects.

Authors, such as Pressman (2010) or Sommerville (2011), deepen and apply project management to software projects. These authors include project management as another existing discipline within the field of software engineering. It is in this scenario where the project management described by these authors is only applicable to software projects, and this is because they describe in great detail the way in which each of its activities should be performed, providing specific tools and guidelines for these types of projects.

The project management methodology specified and described by the PMI (Project Management Institute, 2017) and the agile methodology of SCRUM (Satpathy, 2016) determine, in general terms, everything that a project manager must perform to achieve exercise effective project management, but these disciplines do not go into detail on how project management should be performed for a particular activity. Because of this, these methodologies can be applied to any type of project, and it is up to the project manager to define how to implement the activities described in these methodologies, as well as the tools to be used.

The project management methodology proposed by the Project Management Institute[1] (PMI) is a management methodology that can be applied to any type of project and for this reason, it is one of the most widespread. It stands out for being flexible and

[1] https://www.pmi.org/

adaptable to any type of project; however, from the methodological point of view, it is considered by some as a very bureaucratic and heavy methodology in terms of procedures and requirements.

The body of knowledge that describes for this methodology how project management should be performed, correctly and efficiently, is developed in its completeness by the Project Management Institute (Project Management Institute, 2017) through what is known as the PMBOK[2] . This document is under a constant process of revision and updating by this institution. Authors, such as Lledó & Rivarola (2007), complement these documents by providing practical, concrete, and applied examples for each of the procedures defined in the PMBOK, in order to bring theory and practice closer together.

As the years have progressed, agile methodologies have become very popular, and it is increasingly common to use these methodologies to manage software projects (Appelo, 2011). This adoption is based on the fact that agile methodologies allow building small units of functional software, which is delivered quickly to the customer to correct any problems in the misinterpretation or implementation of requirements, functional failures, or customer dissatisfaction as quickly as possible.

SCRUM is one of these agile methodologies, where agility and continuous delivery are prioritized over processes. Through the definition of short iterations and strictly defined processes, the human is favored to achieve the objectives set in the required times, making the right corrections at the time they are detected. Like PMI, SCRUM has a manual, also called body of knowledge, where the methodology is fully described. (Satpathy, 2016).

According to Alaimo & Salías (2013)the SCRUM methodology is based on 3 fundamental foundations: Inspection, adaptation and transparency, for which team roles, events and artifacts are defined respectively. The complete description and specification of this methodology can be found in the official site of SCRUM, founded by Ken Schwaber, one of the creators[3] of this methodology.

In academia, the use of the main project management methodologies is encouraged, but no research conducted by universities has been found that describes and focuses on measuring specific aspects of how the project management activity is carried out, or how many hours a student dedicates to this type of task.

There are few research papers that focus on investigating the effort devoted to management tasks in software projects in the academic context. One of these works is conducted by Saini & Chomal (2020). In this project, they analyze how effort is distributed in the development of software projects, focusing on Master's degree work. According to the results presented by these authors, the effort in the planning and requirements phase or activities was located in the range between 2% and 15%, with an average of 7%.

When we focus our attention on the industry, many companies are jealous to provide information on the real effort invested in the different tasks performed in their projects since in many cases it is information for internal use, and they do not want the competition to have this knowledge.

In the article presented by Jones (2005), this issue is studied for the software industry, classifying projects according to their size or objective. As revealed in this article, Capers Jones indicates that the effort dedicated to management tasks in software projects, according to the data analyzed, is between 10% and 13%, with 10% being the type of project that most resembles academic degree projects.

[2] https://www.pmi.org/pmbok-guide-standards/foundational/pmbok
[3] https://www.scrum.org/

The point-by-use-case technique used to measure effort in project management is analyzed by Primandari & Sholiq (2015). In their work, they conclude that the effort in management activities reaches 3.8% of the total hours invested. The results obtained and presented by Kassen Shaleh, where he relates management effort to the rate of payment for such tasks, indicate that according to the rate of payment of effort for management tasks in medium or large software projects is 8.34% (as cited in Primandari & Sholiq, 2015, p.83).

A study of similar characteristics is conducted and presented by Mukherjee, Gupta, & Thirugnanam (2016) obtaining other results, which were that the effort on project management tasks stood at an average of 16.14% of the total hours input, with a minimum observed value of 1.82% and a maximum value of 35%.

According to the Project Management Institute (2017) in its body of knowledge, project management is a fundamental competence for any professional who wishes to manage projects and for this reason future professionals must acquire the necessary practical experience. The rest of the authors mentioned above express themselves along the same lines, highlighting the importance of project management and its relationship with the success or failure of projects.

According to Pressman (2010), the effort in project management does not depend exclusively on the characteristics of the project, but it is also important to consider the type of project and the context where it is executed or implemented. It is for this reason that recording measurements in project management tasks in academic degree projects is relevant since these measurements can be contrasted with the industry and the existing literature.

With what has been said above, there seems to be a gap in terms of research work that focuses on measuring the effort of project management tasks in the academic environment and, in particular, in university degree projects. Studies of these characteristics can provide very valuable information to understand how future professionals apply and carry out project management, providing very important inputs not only for academia and universities but also for companies that are in a position to hire the best technical and human talent.

In this research work, a detailed study is conducted on the effort dedicated by students in project management activities, in order to answer the questions: i) Are the hours of project management related to the methodology applied? and ii) How many hours do students dedicate to project management?

In order to answer these questions, the final works of academic degree whose objective is the construction of a software system, where any of the project management methodologies object of this study have been used, will be analyzed. The analysis of the data will be carried out through the use of descriptive statistics according to the concepts presented and proposed by Ross & Valdés Sánchez (2014), paying special attention to the basic statistics used within this branch of statistics (descriptive), such as tendency, dispersion, centralization, median, among others.

## Method

According to the authors, Sampieri Hernández et al. (2014), there are 2 research approaches: quantitative and qualitative, but if we combine both research approaches, it results in a third approach called mixed approach. The approach used for this research work was the quantitative approach since, in the development of this approach, the recording and measurement of the effort (in hours) of the tasks and/or activities of project management in university degree theses is performed.

The absence of intervention by the subject of the study, as well as the non-manipulation of the variables collected, determines that the type of research conducted is non-experimental in nature. This work being categorized as descriptive since its purpose is to determine the effort of students in the tasks of project management in the academic context and, likewise, to validate the relationship of effort with the methodology used in university work.

According to Martínez, (2020) and Ross & Valdés Sánchez (2014), descriptive statistics is used when working with the entire population under study, allowing to organize, describe, analyze, interpret, and present the characteristics of the data analyzed through the use of basic statistics, such as median, minimum, maximum average, bounded mean, variance, standard deviation, among others.

In this work, the access to information and the volume of data analyzed allows for an investigation that includes 100% of the population under study, which is why descriptive statistics (and not inferential statistics) will be used during this research work.

***Participants***

The projects participating in this study come from two private universities in Uruguay: Universidad de la Empresa (UDE) and Universidad ORT Uruguay (ORT). The selection of these universities is mainly due to the fact that the undergraduate projects for the university degree, in most of their projects, consist of the creation of a software system; while in the rest of the universities, the undergraduate thesis consists of a research work or the creation of a prototype product of research, or the access to the undergraduate projects was not possible.

For this research work, information was collected from 250 projects from Universidad ORT Uruguay and 99 projects from Universidad de la Empresa. A total of 349 projects carried out as part of the university degree thesis of undergraduate students in Bachelor's degree and/or Systems Engineering were analyzed. The minimum duration of the projects is 6 months, with a planned extension of 3 additional months. There are very few projects whose duration exceeded the time stipulated by the universities, reaching a maximum of 14 months. The documentation analyzed was collected from the universities' libraries.

The projects analyzed cover the academic periods from 2012 to 2020 inclusive. The analysis of the projects included the review and validation of the information provided by the students in the documentation submitted as degree thesis. For this purpose, the record was analyzed in detail to determine the correctness of the information recorded by the students; in those cases, in which an error was detected in the record, such as in the sum of hours or in the assignment of hours in an incorrect task, as in the case of documentation hours accounted as management hours, the corresponding adjustment was made.

***Data design and analysis***

This study is focused on the analysis of the documentation submitted by the students of the project carried out as a requirement for obtaining the university degree. The first step was to identify and quantify the projects that recorded the effort (in hours) of tasks and/or activities dedicated to project management and the management methodology used. From the analysis, 3 methodologies were identified as being used in more than 96% of the projects: the methodology proposed by the Project Management Institute (PMI), project management specific to software projects (PMS), and the SCRUM framework. The rest of the methodologies that were used, such as Kanban, OpenUp, etc., were discarded from this work since there were not enough projects. The total number of theses for each methodology is presented in Table 1.

Table 1
*Number of projects analyzed according to the applied methodology*

| Number of Projects | Methodology | Universidad ORT Uruguay | Universidad de la Empresa |
|---|---|---|---|
| 115 | Specific software management | 42 | 73 |
| 35 | PMI Methodology | 17 | 18 |
| 199 | SCRUM | 191 | 8 |
| 3 | OpenUp, Kanban, etc. | 0 | 36 |
| 352 | | 250 | 99 |

*Note:* Source: Own elaboration

A dataset was created and organized with the information obtained in the previous step, so that each project to be included had to satisfy two conditions: 1) to have recorded the methodology used and 2) to have recorded the number of hours. Stacked bar charts and histograms and tables with the relevant statistical information were used to facilitate the interpretation and comparison of the data.

This dataset was subjected to various analyses including: analysis of the percentage of project execution as a function of the management methodology applied per university and another histogram with the complete set of data, effort dedicated to project management tasks in 5% intervals per university and with the complete set as well as histograms of the effort measured in hours for each methodology and for all projects as a whole.

## Results

### *Project management hours effort survey*

The documentation submitted for a total of 250 ORT Universidad ORT Uruguay projects covering the periods 2012-2020 was analyzed, as presented in Table 1. In 33.6% of these projects analyzed (84 projects), no evidence was found in the written documentation on recording or measuring hours in project management tasks, while the remaining 66.4% of the projects (166 projects) had provided evidence of the recording of activities related to project management. According to these percentages, there are a total of 166 valid projects to measure project management effort as shown in Table 2.

Table 2
*Valid projects according to methodology applied and university of origin*

| Number of Projects | Methodology | Universidad ORT Uruguay | Universidad de la Empresa |
|---|---|---|---|
| | | Valid | |
| 81 | Specific software management | 23 | 58 |
| 30 | PMI Methodology | 13 | 17 |
| 134 | SCRUM | 130 | 4 |
| 245 | | 166 | 79 |

*Note:* Source: Own elaboration

With regard to the company's university and out of a total of 99 projects analyzed (see Table 1), the percentages obtained, as shown in Figure 1, do not present major

variations. 20.2% (20 of the projects) did not present evidence of having recorded project management hours, while 79.8% did present written evidence of having done so, for a total of 79 valid projects (see Table 2).

From a general point of view, in the academic field and for the projects analyzed from both universities, 29.8% (104 projects) of a total of 349 projects did not provide written evidence of the recording of hours spent on project management tasks, while the remaining 70.2% (245 projects) provided evidence of having done so.

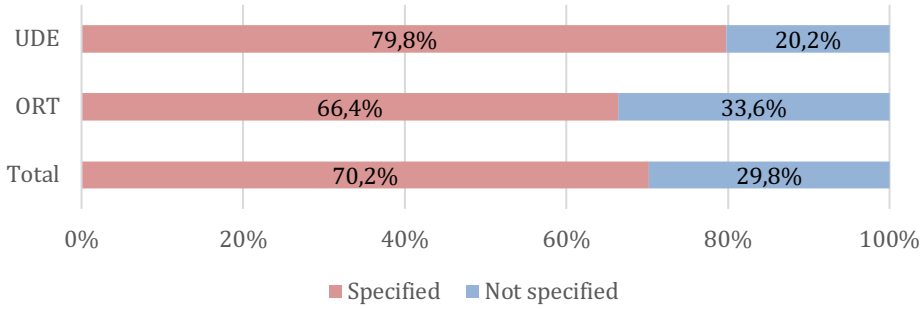


*Figure 1.* Percentage of projects with specified management hours.
*Note:* Source: Own elaboration

The Universidad ORT Uruguay projects show a strong tendency to use scrum as a methodology or framework for project management, thus relegating the PMI methodology or software-specific project management. The detail of the percentages obtained for each university and each methodology is shown in Figure 2.

On the other hand, unlike the ORT university, the company's university presents a strong tendency towards traditional methodologies, being software-specific project management with 73.4% the most used methodology, in second place, with 21.5% the PMI methodology, and lastly scrum with only 5.1% of the projects.

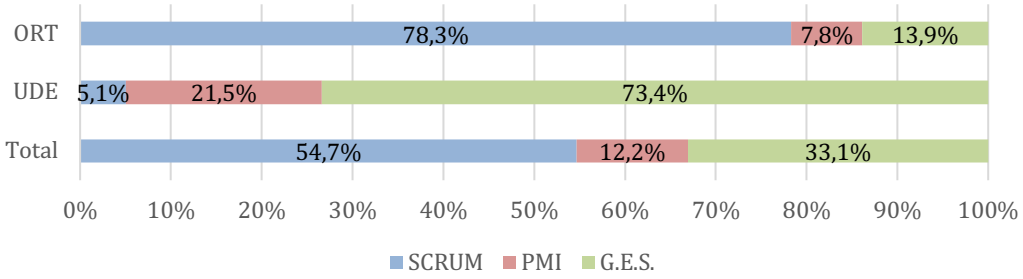


*Figure 2.* Projects discriminated according to the methodology applied
*Note:* Source: Own elaboration

From the previous figure, it can be deduced that both universities present different preferences in terms of the management methodology used by students to carry out project management in undergraduate theses. This difference may be due to the characteristics of the undergraduate projects, the focus of the academic curriculum, or some other factor that should be further analyzed.

When totaling the projects from both universities, and taking into account that ORT contributes more than twice as many projects as UDE, it can be seen that almost half of the projects are based on traditional methodologies for project management (12.2% PMI + 33.1% G.E.S.), while the other half (54.7%) uses scrum (see Figure 2).

The quantification of the projects according to methodology and university of origin were presented in Table 2.

The effort dedicated to tasks related to project management shows small differences when comparing the data obtained in both universities. In most of the projects analyzed, the number of hours dedicated to these tasks was between 5% and 15%, and to a lesser extent, with a dedication of more than 15% or less than 5%.

As can be seen in Table 3, both universities present a very similar percentage of projects, with a difference of only 3% for the number of projects whose management hour record is less than 5%, being this percentage 15.7% and 12.7% for ORT and UDE, respectively.

This behavior is not observed in the interval between 5% and 10%. According to the results obtained, the difference between the number of ORT and UDE projects is 18.5%, where 59.5% of the total number of UDE projects analyzed are in this interval, in contrast to ORT, where only 41% of the projects analyzed are in this interval.

The range between 10% and 15% does not show significant differences and both universities have almost the same percentage of projects in this range with 24.7% and 24.1% for ORT and UDE, respectively, a difference of only 0.6%.

Finally, the number of projects in which the number of management hours exceeded 15% shows a difference of 18.5% between the two universities. While 18.7% of the ORT projects analyzed had a record higher than 15%; at the UDE, this behavior was only observed in 3.8% of the projects analyzed. The details of the results obtained are presented in the following table.

Table 3
*Breakdown of projects by percentage of hours dedicated to project management*

| | **Universidad ORT Uruguay (ORT)** | | **Universidad de la Empresa (UDE)** | | **Total** | |
|---|---|---|---|---|---|---|
| | # | % | # | % | # | % |
| **Less than 5%.** | 26 | 15.7% | 10 | 12.7% | 36 | 14.7% |
| **Between 5% and 10%.** | 68 | 41.0% | 47 | 59.5% | 115 | 46.9% |
| **Between 10% and 15%.** | 41 | 24.7% | 19 | 24.1% | 60 | 24.5% |
| **Greater than 15%.** | 31 | 18.7% | 3 | 3.8% | 34 | 13.9% |

*Note:* Source: Own elaboration

When considering all the projects analyzed, it can be observed that 71.4% of the projects are located in the 5% to 15% range. According to Jones (2005), software development projects present an effort in management tasks in the range of 10% of the total project hours. If it is considered that the projects analyzed are in an academic context and are executed by future professionals, it can be considered that the range of 5% to 15% is a range that, to a greater or lesser extent, is very close to the industry.

The statistical data calculated for both universities are shown in Table 4. As can be seen, there are no considerable or relevant differences between the projects of both universities, with the exception of the minimum or maximum that deviate from the median. It is important to note that the mean, when excluding the 10% of the lower segment and the upper segment, returns a value very close to the average and the median, which means that the extremes do not affect the dataset.

Table 4
*Statistics on management hours by university of origin*

| | UDE Hours Management % | ORT Hours Management % |
|---|---|---|
| **Average** | 8,3% | 10,5% |
| **Trimmed Median (10%)** | 8,2% | 9,8% |
| **Median** | 7,8% | 9,0% |
| **Minimum** | 2,8% | 1,0% |
| **Maximum** | 16,7% | 45,7% |
| **Standard deviation ($o^2$)** | 3,1% | 6,8% |
| **Variance (o)** | 0,1% | 0,05% |

*Note:* Source: Own elaboration

### *Effort according to applied methodology*

A total of 134 projects were used to analyze the effort dedicated to the management of projects that were managed using the SCRUM methodology. This dataset was used to construct the histogram presented in Figure 3. The shape of the histogram (drawn curve) resembles a bell or normal distribution, with a slight increase for projects whose effort is greater than 20%. These results are not surprising because these are projects carried out by students and, due to the academic nature of these projects, particular situations or behaviors may arise. In real projects there may also be particular situations that may cause some projects to escape from the typical values.

The histogram in Figure 3 shows that 93 projects (69.4%) are between 5% and 15%, 20 projects (14.9%,) with an effort below 5%, and 21 projects (15.7%), with an effort above 15%.

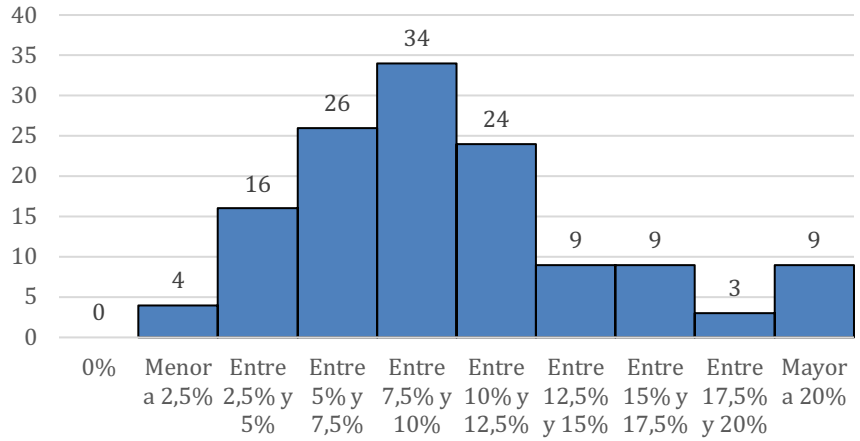


*Figure 3.* Project management effort in projects managed with SCRUM
*Note:* Source: Own elaboration

In the histogram obtained for the 30 projects, whose execution was managed using the PMI methodology and which is presented in Figure 4, it can be seen that the curve drawn in this graph has an irregular shape as in a bimodal classification. This means that there is a possibility that there are 2 groups of projects, where the peaks are presented, with distinctive characteristics, the analysis of these projects and their characteristics is beyond the scope of this work. Of the total number of projects analyzed, 24 projects,

which is equivalent to 80% of the projects, provided evidence that places the effort spent on project management tasks between 5% and 15% of the total hours executed in the project. Only 2 projects (6.7%) had an effort lower than 5%, and 4 projects (13.3%) had an effort higher than 15%.

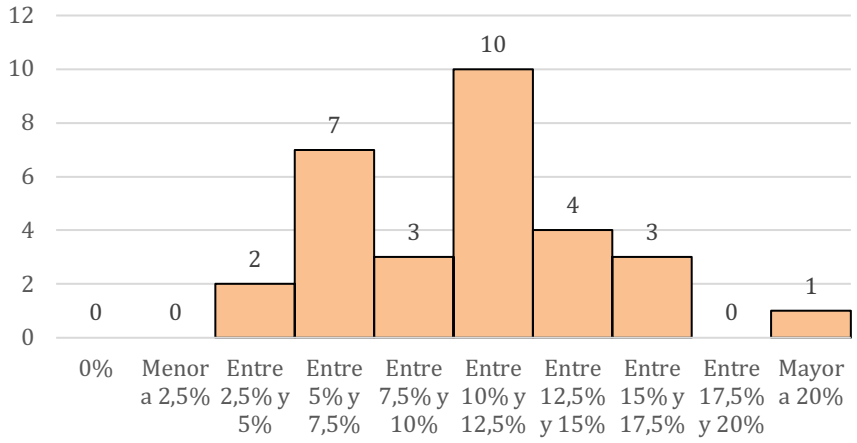


*Figure 4.* Project management effort in projects managed with PMI methodology
*Note:* Source: Own elaboration

The histogram presented in Figure 5 was constructed with the data obtained from the 81 university degree projects that carried out the project management using the specific software management methodology.

Figure 6 reveals that 58 projects of those analyzed (71.6% of the total) state that the effort expended for project management activities or tasks is between 5% and 15%, while 14 projects (17.3%) devote less than 5% effort and 9 projects (11.1%) devote more than 15% effort.

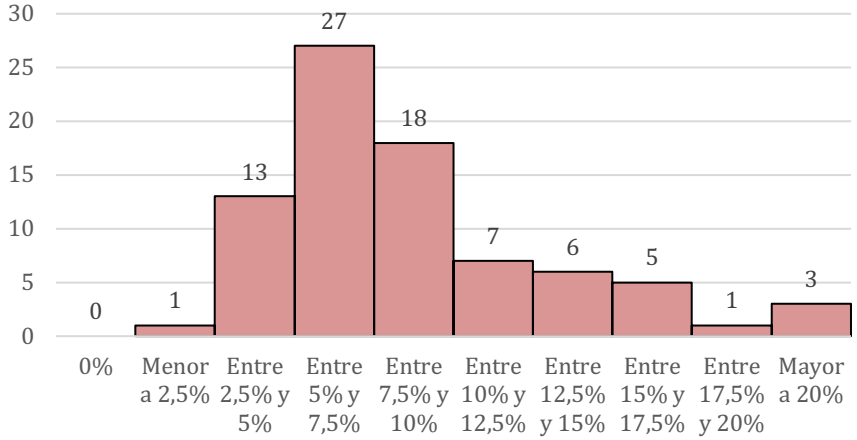


*Figure 5.* Project management effort in projects with specific software management
*Note:* Source: Own elaboration

The analysis of the data for each methodology allows an objective comparison of the values obtained and the drawing of appropriate conclusions. However, it is also possible to analyze the data from the academic point of view for all the degree projects, regardless of the methodology applied. As shown in Figure 6, 175 projects (71.4% of the 245 projects included in this work) show evidence that the effort invested in project management tasks is between 5% and 15%.

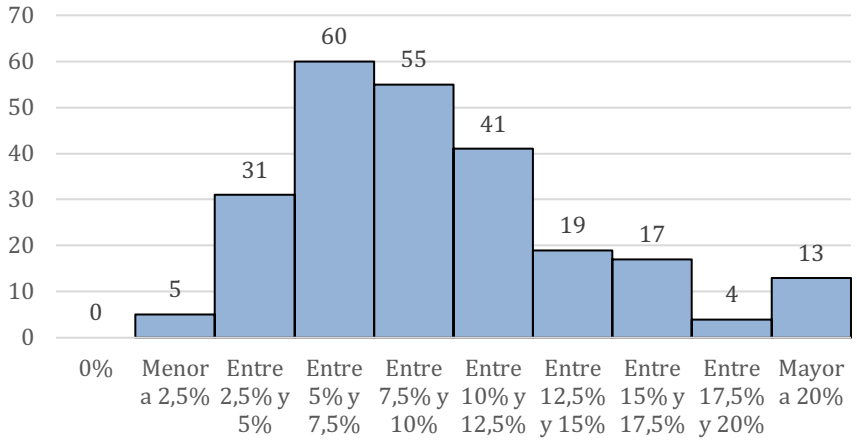


*Figure 6.* Project management effort regardless of the methodology used
*Note:* Source: Own elaboration

From the statistical data presented in Table 5 and Figure 7, it can be seen that there are no significant differences between the management methodologies applied by the students. The distribution of projects, according to the methodology applied, indicates that the methodology most used by the students in the 245 projects analyzed is SCRUM, followed by specific software management (SSM) and, finally, the PMI methodology with 134, 81, and 30, respectively. The total number of hours of the projects (based on averages) show little variation among the different methodologies: SCRUM, PMI, and software-specific project management with 1737, 1646, and 1561, respectively. The average duration of the undergraduate projects analyzed when not discriminated, according to the management methodology applied, is an average of 1666 hours.

Table 5
*Statistical data broken down by methodology applied*

| | SCRUM | PMI | Specific software management (SSM) | Total (General) |
|---|---|---|---|---|
| **Number of projects** | 134 | 30 | 81 | 245 |
| **Average (Total hours)** | 1737 | 1646 | 1561 | 1666 |
| **Average (Project Management)** | 10,2% | 10,5% | 8,7% | 9,8% |
| **Trimmed Median (10%)** | 9,5% | 10,2% | 8,3% | 9,1% |
| **Median** | 8,7% | 10,2% | 7,3% | 8,5% |
| **Minimum** | 1,0% | 3,0% | 2,0% | 1,0% |
| **Maximum** | 45,7% | 25,3% | 24,9% | 45,7% |
| **Standard deviation ($o^2$)** | 6,8% | 4,5% | 4,5% | 5,9% |
| **Variance (o)** | 0,5% | 0,2% | 0,2% | 0,4% |

*Note*: Source: Own elaboration

The effort dedicated to management tasks declared and recorded by the students in the university degree theses does not show significant differences according to the methodology applied. The application of PMI and SCRUM methodology are at 10.2% and 10.5%, respectively, while the specific management of software projects is a little lower with an average of 8.7%. As expected, the average (at 10%) maintains the relationship and allows us to discard the extremes (outsiders) that may affect the

calculated value. The values obtained 9.5%, 10.2%, and 8.3% do not differ significantly when contrasted with the averages presented above. There are also no considerable differences in terms of variance and standard deviation.

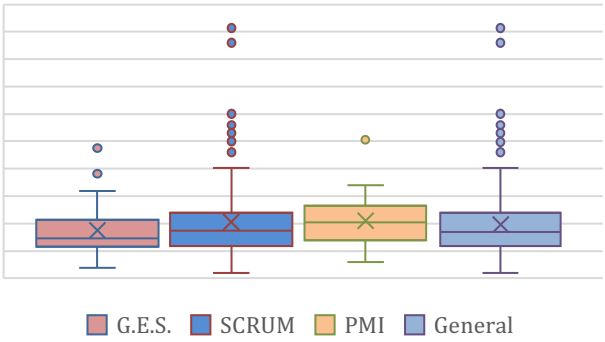


*Figure 7.* Box plot for the methodologies applied.
*Note:* Source: Own elaboration

With the results obtained, it can be observed that the different methodologies applied show very similar values among them, with few outliers and with a median value that does not show very dissimilar values among the methodologies analyzed. Regarding the minimum and maximum values observed, it can be seen that, in the case of the minimums, there are no relevant differences between the different methodologies, although the minimum value recorded seems to be the result of a project whose measurement was not correctly carried out. Regarding the maximum, SCRUM is the methodology where the maximum is four times higher than the average; this being one of the edge cases. For the rest of the methodologies, the maximum was around 25%.

## Discussion and conclusions

At the beginning of this research work, the objective was to answer the following two research questions:

i) Are the project management hours related to the methodology applied?
ii) How many hours do students spend on project management?

To answer these questions, 245 undergraduate projects were analyzed from two private universities in the country, the Universidad ORT Uruguay and the Universidad de la Empresa.

Based on the results obtained and the percentages calculated, Universidad ORT Uruguay is the university with the highest number of projects where no project management hours were recorded with a percentage of 33.6%, compared to the 20.2% recorded in the company's university. If we analyze the percentage of projects that did not record management hours for the total number of projects (without discriminating by university), the percentage obtained is approximately one third of the total number of projects (29.8%).

Since this is a critical task, which is directly related to the success or failure of projects, 29.8% seems to be a very high percentage and should not be taken lightly. This means that there is no evidence, or it is not presented, indicating that students perform fundamental tasks, such as measurement, recording of work performed, follow-up, and control; basic activities of a project manager. Based on the percentage of projects that do not provide evidence of this work or that these activities were not performed, it is evident that universities should focus on stressing the relevance of performing this task, and that

students understand the importance, its impact, how to perform it, and the need to record this information.

With respect to the projects that did register the effort in management tasks, a set of observations and conclusions can be made, which are detailed below.

According to the results obtained, there is no evidence to indicate that the methodology applied is related to the effort students devote to project management tasks. The difference between the calculated bounded mean for the 3 methodologies analyzed did not exceed 1.9%; these results being 8.3%, 9.5%, and 10.2% for SCRUM, PMI, and GES, respectively. This means that regardless of the methodology used, the percentage of hours spent on these tasks does not differ significantly.

It is interesting to note that the PMI methodology, being a traditional methodology that focuses on the documentation and application of clearly defined processes, does not demonstrate an overload in the effort dedicated to management tasks over the other methodologies. Before conducting this research work, it could have been hypothesized that PMI methodology or software-specific project management require more management efforts than agile methodologies and in particular SCRUM; however, in this work, this hypothesis is discarded.

In this paper, sufficient evidence is presented to answer negatively the first research question: Are the hours of project management related to the methodology applied? According to the results obtained and presented throughout this article, we can rule out the existence of a relationship that indicates that the methodology applied throughout a project is related to the effort that students must make in project management tasks, at least in the academic context. However, having said that, it is important to highlight that there are 2 areas of knowledge that were not applied during the projects, these being supplier management and cost management. It is quite possible that, in real projects, by including these areas of knowledge, the management hours using PMI would be slightly higher than those used in this research work.

Answering the following question: How many hours do students dedicate to project management? It was the second objective of this research work. Obtaining an answer to this question based on the analysis of academic projects allows us to compare whether projects in the academic environment have the same level of dedication as real projects.

Based on the results obtained, it can be affirmed that in an academic context the effort dedicated by students to project management tasks is between 5% and 15% of the total hours dedicated to the project. As expected, there were some projects that deviated from the defined interval, in order to determine the causes, it is necessary to perform specific analyses; however, with the analyzed documentation, it was not possible to make any conclusion. It is advisable that in these cases the correctors perform this analysis and document in the projects the reasons for the deviations in order to have the necessary information available when required.

The results obtained and the defined range of 5% and 15% of the total project hours in management effort seem to be more consistent with the results expressed by other authors, as presented in the literature analyzed, as well as with the industry. Remember that Jones (2005) placed the effort in 10%, in the academic context and, being the students in charge of project management, a deviation of ±5% seems to be within the acceptable range, being these values very close to those obtained in real projects.

In conclusion, through this work and with regard to the academic context, it is evident that there is no relationship between the percentage of hours dedicated to project management tasks and the methodology used. According to the results presented,

between 70% and 80% of the projects analyzed showed evidence that the total hours spent on management tasks were between 5% and 15%, regardless of the methodology used.

### *Reflections and limitations*

Universities are a fundamental element in the training of professionals, but even more important in the training of people who, through their skills, contribute to the society in which they are immersed. It is in this context where it is increasingly necessary to train better professionals, not only in terms of technical skills but also in social skills.

The academic plans of universities must be constantly changing, adapting to the demands of industry and society, and it is for this reason that measuring the correlation between what is taught and what industry demands is a necessity. However, in this work we measure some parameters that allow us to contrast the results obtained in the academy, for project management, with those presented in the industry. The purpose of this contrast of results is to verify whether the academic content and the university's demands on students are in line with what the industry needs or demands, or if, on the contrary, there is a gap between the academy and the industry.

This work focused on analyzing, quantifying, and presenting the results obtained from measuring the effort dedicated to one of the tasks that is closely linked to the success or failure of projects, such as project management.

During the course of this work, various difficulties have arisen that had to be overcome and that limited the number of projects, such as the existence of projects where adequate measurements, documentation or records were not made. For this reason, it is advisable for universities to emphasize the importance of measuring the effort of the tasks carried out throughout the project, giving clear and precise guidelines on how it should be done and what should be measured.

### *Continuity proposals*

This work presents the opportunity to provide a look at project management from the point of view of academia and students, laying the groundwork for similar future work for the rest of the activities involved in a university degree thesis. In particular, it seems interesting to carry out research that focuses on the effort in development, testing, and documentation individually, as well as work that combines and presents this information in a unified way. With the results obtained, it can be investigated whether any of these tasks are directly related to the methodology used, as has been done throughout this work.

Another interesting avenue to explore is to measure project management effort in other disciplines and contrast it with the results presented in this paper in order to verify and compare the similarities and discrepancies in the effort devoted to project management tasks between software projects and projects in other industries.

Finally, this work aims to collaborate with universities by providing more information on the nature and execution of undergraduate projects, focusing on project management in the academic context. The ultimate goal of this research is to provide universities with real data from their students' own projects. Universities should not forget that they work by and for students; continuous improvement is not an option but an obligation.

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**Receipt date:** 12/14/2021
**Revision date:** 01/18/2022
**Acceptance date:** 03/29/2022

PROJECT, DESIGN AND MANAGEMENT

ISSN: 2683-1597

**How to cite this article:**

Granados Saavedra, M. & Canto-Ramírez, J. L. (2022). Cursos abiertos masivos en línea (MOOC) y capacitación del personal: la experiencia del sistema penitenciario costarricense. *Project, Design and Management,4*(1), 69-90. doi: 10.35992/pdm.4vi1.903

# MASSIVE OPEN ONLINE COURSES (MOOC) AND THE TRAINING OF THE STAFF: THE EXPERIENCE OF THE COSTA RICAN PENITENTIARY SYSTEM

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**Abstract**. A research work was carried out to determine and prioritize the training requirements of the Costa Rican Penitentiary System personnel, to analyze the feasibility of satisfying them through the use of MOOC (Massive Open Online Course). A mixed, exploratory type investigation was carried out by applying a training needs questionnaire, applied to the headquarters of the Institution, to know and prioritize the training needs of the personnel. In addition, the course offerings of various MOOC platforms were analyzed, and it was reviewed which MOOC platforms presented courses that could be applied to satisfy the existing requirements. Similar research antecedents were found, related to the diagnosis of training needs and the application of MOOC for continuous professional training in public and private organizations. The research allowed the identification of platforms that offer MOOC applicable to the satisfaction of the requirements of the Costa Rican Penitentiary System staff. The results obtained allow us to conclude that it is feasible to use MOOC in the training of the referred personnel, recommendations are generated for future research on the subject and the need to carry out a study about the effect of the lack of training in the Costa Rican Penitentiary System is raised.

**Keywords:** Training, government, distance training, employee, continuous training.

# CURSOS ABIERTOS MASIVOS EN LÍNEA (MOOC) Y CAPACITACIÓN DEL PERSONAL: LA EXPERIENCIA DEL SISTEMA PENITENCIARIO COSTARRICENSE

**Resumen**. Se realizó un trabajo de investigación para determinar y priorizar los requerimientos de capacitación del personal del Sistema Penitenciario Costarricense, a fin de analizar la factibilidad de satisfacerlos mediante el uso de MOOC (Massive Open Online Course). Se ejecutó una investigación de

tipo mixta, exploratoria, mediante la aplicación de un cuestionario de necesidades de capacitación, aplicado a las Jefaturas de la Institución, para conocer y priorizar las necesidades de capacitación del personal. Se analizó además, la oferta de cursos de varias plataformas MOOC y se revisó cuáles plataformas MOOC presentaban oferta de cursos que pudieran ser aplicados en la satisfacción de los requerimientos existentes. Se encontraron antecedentes de investigaciones similares, relacionadas con el diagnóstico de necesidades de capacitación y la aplicación de MOOC para la formación profesional continua en organizaciones públicas y privadas La investigación permitió identificar plataformas que ofrecen MOOC aplicables a la satisfacción de los requerimientos del personal de Sistema Penitenciario Costarricense. Los resultados obtenidos permiten concluir que es factible utilizar MOOC en la capacitación del personal referido, se generan recomendaciones para futuras investigaciones en el tema y se plantea la necesidad de ejecutar un estudio sobre el efecto de la falta de capacitación en el Sistema Penitenciario Costarricense.

**Palabras clave:** Capacitación, gobierno, formación a distancia, empleado, formación continua.

## Introduction

The term MOOC refers to the acronym for Massive Open Online Courses, consisting of free and specialized online courses, aimed at anyone interested in the subject, taught by professional experts in higher education. McAuley, Stewart, Siemens, & Cormier (2010) define MOOCs as an online phenomenon that has gained momentum in recent years, where the MOOC integrates the connectivity of social networks, the facilitation of a recognized expert in the field of study, and a series of freely accessible online resources. By its massive nature, a MOOC is oriented to the participation of several hundreds or thousands of students, who self-organize their participation according to learning objectives, knowledge, and skills of common interests. From its theoretical perspective, a MOOC does not require payment of registration fees, nor does it require prerequisites for access to the course. They are characterized by the fact that students have different expectations in their participation, as well as by the fact that they do not provide formal accreditation models. The first known MOOC was a course taught by George Siemens and Steven Downes in 2008, which was part of their thesis on connectionism. The result of this effort was later named MOOC by Dave Cormier and Brian Alexander (Downes, 2008). From this initiative, both higher education institutions and private companies have opened MOOC offerings, making them available to users, whether they are professionals or people who, without having specific training in the subject, are interested in it.

We can mention for example the project of Banco Santander and Telefónica, developed in 2013, called MiriadaX (https://miriadax.net/home), Coursera developed in 2011 by Stanford University (https://es.coursera.org), edX (https://www.edx.org/es/course) founded in 2012 by the Massachusetts Institute of Technology and Harvard University or Udemy (https://www.udemy.com) founded in 2010 by Eren Bali, Oktay Caglar, and Gagan Biyani.

Yuan, Powell, and Cetis (2013) described MOOCs as a disruptive innovation in higher education due to their free, accessible, and massive nature. It should be remembered that an innovation is considered disruptive when it creates a new market through the introduction of a new type of product or service, which tends to be simpler, cheaper, more reliable, and more convenient than previously existing products. These disruptive products, with no value in the conventional market, become stronger selling points in emerging markets and are characterized by two elements, namely technology and business model innovation.

MOOC is an acronym of its abbreviation: Massive, the courses must be massive, that is, with as many participants as possible since anyone who wishes to enroll in it could do so. Open, because there are no restrictions or requirements to access it. This is possible because they use resources that are not proprietary and are available to the public free of charge. These courses are hosted on free access platforms (under registration) and, in general, the resources are published under Creative Commons licenses, which facilitate the use and sharing of creativity and knowledge. The online feature implies that the activities, evaluation, communication with facilitators and among peers are carried out remotely, in a virtual context. Participants can enroll from anywhere in the world, using technological platforms with the capacity to support a large flow of participants. Course, because they are learning-oriented courses.

Meltem Huri Baturay (2015) adds two characteristics to MOOCs, related to the participatory and distributed aspects. Participatory, as learning in a MOOC is enhanced by voluntary participation in both the creation and sharing of personal contributions and interactions with the contributions of others and distributed, as the MOOC is based on the connectivism approach; therefore, any knowledge must be distributed through a network of participants. Most of the course activity takes place in a social learning environment, where participants interact with the material and others' interpretations of it. Course readings and other learning materials act as starting points for discussion and reflection.

Sevillano, Vázquez, and Aguaded, cited by Aguaded-Gomez (2013), consider that the MOOC learning model can be a magnificent opportunity to take advantage of the possibilities offered by technologies, generating quality "ubiquitous" and "emergent" learning.

In turn, Fidalgo-Blanco et al (2014) point out that MOOCs are an evolution of the Open Course Ware movement. OCW for its acronym in English.

According to Teixeira et al (2015), MOOCs favor the social inclusion of people in education, disseminate formal and informal knowledge to a large audience, and facilitate the innovation of teachers in their pedagogical actions.

Cruz-Benito et al (2015) cite that some of the MOOC modalities encourage the creation of learning communities around their topics. A CISCO report, published in 2010, called "The Learning Society," points out that educational systems need to change since in the past learning was competitive, coercive, and paternalistic, while today it is collaborative, globalized, and universal. From this perspective, access to MOOC platforms offers users and members of the community interested in the subject of reference, the possibility of developing the knowledge, skills, and abilities required to meet the challenges imposed by the new characteristics and social trends of today.

Due to the fact that the Costa Rican Prison System has seen a reduction in the number of resources available for the training of its personnel, an amount that has decreased from 76,027,000 colones in 2013 to 13,113,659 colones in 2021[1] , there is a need to look for alternatives that allow providing quality training for personnel, without the need to invest large amounts of money.

According to information obtained from the Human Resources information system, the Costa Rican Penitentiary System has 5292 employees, who belong to 219 types of positions, distributed in 47 units that are geographically dispersed throughout the country. Many of the workers work rotating shifts and due to their functions cannot leave

[1] Source, institutional budgets, visible on the website http://www.mjp.go.cr/Transparencia/RedTransparencia.

their jobs, so as not to neglect the care of the persons deprived of liberty in the institution's care. The above reasons prompted an investigation to verify whether the use of MOOCs was a feasible option for staff training.

Continuous training is a widely spread and accepted tool for the achievement of the organization's objectives, representing an organizational strategy that involves the direction and management of human resources (Pineda, 2007). This training, in recent years, has experienced an increase in the consumption of online training courses, whose motivation is centered on the effects of the economic crisis, which makes companies seek training actions that yield short-term profitability and forces professionals to prepare themselves in the best way to face the excess of labor supply (Ponce et al, 2010).

MOOCs are high quality training services that do not require the deployment of a large number of logistical activities for the attention of people, nor do they require the travel of attendees to a specific place or at a specific time, which reduces operating, logistical, and travel costs, savings that are important, considering the reduction in the budget for training activities that the Costa Rican Prison System has suffered.

In the research carried out, the existing training requirements of the Costa Rican Penitentiary System were analyzed and prioritized, with the objective of proposing the use of massive open online course platforms for the development of virtual training activities in their different areas of work, in the professional, technical, police, and administrative fields.

According to Reza (2006), the diagnosis of training needs allows to know the lack of knowledge, skills, attitudes, and aptitudes of people to effectively perform their job and reach their level of competence, which is the basis of a training plan, which must be constantly renewed, according to the organizational dynamics and which constitutes the success of the continuous process of professional training.

Moreira (2013) points out that the training needs analysis serves to establish the objectives of the program, as well as to identify the skills and knowledge necessary for employees to perform their work, so as to improve performance and productivity and, finally, to analyze potential participants, ensuring that the program fits the levels of education, experience, competencies, attitudes, and motivations of the participants.

Technology as a means of enabling new training spaces for staff, offers the Prison System the possibility of overcoming the difficulties arising from the geographical dispersion of staff, the existence of rotating schedules, and the lack of financial resources. Through the use of MOOCs, continuous learning is promoted, democratizing access to knowledge through the publication of free open online courses by prestigious universities or other professional groups.

The Costa Rican Penitentiary System was created by Law No. 4762 "Law Creating the General Directorate for Social Adaptation," which establishes its purposes and functions. It is made up of a Directorate, a Sub-Directorate, the National Institute of Criminology, an Administrative Department, the Training School, the Technical Department, the Industrial and Agricultural Department, and the Architecture Department. It also has institutional and semi-institutional penitentiary centers, community level offices, centers for the juvenile criminal population, centers for the female population in conflict with the law, Integral Care Units, as well as Social Insertion Units, Repatriation Units, and the Unit for the care of persons subject to monitoring with electronic devices. The same budget program includes the Prison Police Directorate,

made up of the Departments of Supervision, Custody and Penitentiary Surveillance, Plans and Operations, Prison Intelligence, and Information and the Weapons Unit[2] .

As a result of the decrease in the budget allocation for training activities, the Costa Rican Penitentiary System has not been able to allocate sufficient resources to meet the training requirements of its employees, an objective that has been partially achieved by signing cooperation agreements with other public institutions, professional associations, non-governmental organizations or individually and, privately, through the investment of resources and the employees' own time, the latter having an impact on the employees' family assets and their free time.

Given the budgetary impossibility of allocating resources to meet the existing training requirements for the proper fulfillment of organizational goals and objectives, the Costa Rican Prison System must seek training and education alternatives that, with a minimum investment, allow workers to access world-class training, This is all in pursuit of operational excellence and the fulfillment of the mission that Costa Rican society has entrusted to it as the body responsible for the enforcement of judicial sentences handed down for the deprivation of liberty or other types of criminal sanctions.

Similar studies conducted by several authors were found as background to the research. Atiaja and Garcia (2020), in their study, "MOOCs an alternative for continuous training," analyze the potential of MOOCs for the continuous training of professionals. This is because educational institutions have adopted these courses, motivated by the health emergency caused by COVID-19, since thousands of people have resorted to them in order to train and acquire knowledge, competencies, and skills to perform in their work activities because, as a result of the pandemic, the education model migrated from a traditional model to a virtual one. The study was descriptive, applying historical-logical methods, analysis, and synthesis, ending with generalization-abstraction, through the use of primary and secondary bibliographic sources. The main findings are related to the fact that MOOCs have evolved according to the increase of interest in online learning, representing an alternative for continuous training due to their potential to meet the needs of updating, renewal or training of professionals in order to acquire competences or skills demanded by the knowledge society. In this sense, it is necessary to reconstruct MOOCs in order to overcome the pedagogical and technological challenges faced by these courses in order to improve the quality of teaching and learning.

Ruiz (2019), carried out a research entitled, "Impact of the application of a MOOC methodology in Ecuadorian university teaching," whose main purpose was the development of a methodology to define massive courses aimed at Ecuadorian civil servants linked to higher education. Its objective was to design a methodology to facilitate and improve the updating and improvement of the Ecuadorian civil service, in the educational field, through massive virtual processes since the Ecuadorian government has made achievements in public infrastructure and in the implementation of social policies, so it is essential to invest in human talent. This is one of the main problems of the education sector in Ecuador, for which the application of MOOCs becomes a necessity in terms of the optimization of economic and human resources. The research methodology was based on a multi-referential, multidimensional, and interpretative research, whose basis was the complement of methods such as case studies, interviews, surveys, statistical analysis, and triangulation of results, mixing field and documentary-bibliographic research at a descriptive-evaluative-correlational level. The main findings were that the methodology fulfilled its objective, allowing the construction of didactic material and the

[2] Source http://www.mjp.go.cr/Dependencias/DGASDetalles

development of activities, positioning itself in the teachers as a systemic process guiding the efficient development of a course. The leaders of the participating Universities expressed the importance of the methodology of the academic project, highlighting that this instrument allows making the decision to support the design of a MOOC for the instruction of the staff.

Aguilar de la Garza (2019) conducted a research called, "Model of quality indicators for massive open online courses (MOOC)," whose objective was to identify indicators to evaluate the quality of MOOCs offered as a strategy to strengthen teacher training and its application in the MOOC-LGEE-TEC offered through Coursera, in addition to analyzing the suitability of the use of MOOCs in training strategies for teacher professional development. Its main motivation was to measure the opportunities offered by MOOCs for the development of teaching professionals, considering both the need for continuous training to improve the competencies of practicing educators, and the need to complement the initial training of professionals who graduate year after year from teacher training colleges. Its general objective was to design a MOOC oriented to teacher training, based on a quality model validated by specialists, analyzing both the results of quality indicators and the learning obtained by the participants. A quantitative approach was applied, through a case study; using as instruments for data collection, an inventory of quality indicators from previous research, an administered questionnaire and diagnostic tests. Its main findings corroborate that in order to measure the success or quality of a MOOC, it is necessary to go beyond the number of participants enrolled or who complete the course satisfactorily since factors related to the acquisition of knowledge of the participants, as well as the promotion of self-regulated learning for professional development, must be considered.

For their part, Toapanta and Gavilanes (2018), in their research, "Metaphorization in MOOC courses for the acquisition of professional competencies," whose objective was to determine the relationship between metaphorization in MOOCs and the acquisition of professional competencies in the staff of the Ambato General Hospital of the Ecuadorian Social Security Institute, seeking to improve the learning process in the continuous trainings offered by that Hospital to its administrative, medical, nursing, and service staff through the application of metaphorical and iconographic contexts in MOOC courses. Through the use of MOOCs of metaphors and iconographies adapted to stories of any subject matter, they generated in the participants an innovative and creative environment for the development of professional competencies through the fulfillment of goals. The research had a propositional critical approach, using a bibliographic and field modality; of descriptive type, using methods such as the use of Cronbach's Alpha coefficient and the Wilcoxon signed ranks test. The conclusions of the research show that metaphorical MOOCs benefit the development of knowledge, skills, and attitudes, contributing to personal and professional training; as well as that the use of metaphors contributes to new online training alternatives. The proposal that was part of the research was implemented through the use of the MOODLE platform, on which a metaphorical MOOC was developed, applying the PACIE methodology, which constitutes a model that modifies the teaching role by an efficient tutorial action, motivating and carrying out the necessary accompaniment to reduce the dropout rates in virtual teaching courses. The course reached the participation of most of the Hospital's professionals, who passed the course and obtained their certificate. The main limitation of the research was that most of the staff had not taken online courses in recent years and, therefore, had not worked in MOOCs with graphical environments.

Flores (2018), in the research conducted on the online training of the National Forestry Commission (CONAFOR), seeks to define a proposal for the creation of a self-sustainable virtual training program for CONAFOR since, in recent years, the Institution suffered a series of budget cuts, which affected the resources available to develop the training courses that are part of the annual training needs diagnosis. The objective of the intervention project was to define the functionality of designing and implementing an online course for the training of CONAFOR personnel, executing a pilot test for the creation of an online training program. The instruments used to collect information were the survey, the interview, the cause-and-effect matrix, and the SWOT matrix. Information was collected through e-mail and the application of a survey through the Survey Monkey site. The course applied in the pilot experience was developed using the MOODLE platform. The results of the research confirm the functionality of the design and application of an online course, which, according to the Commission's training manager, would constitute the basis for the development of a virtual training program that would have no operating costs and would strengthen proposals, in addition to reducing time. The participants stated that if the course is simple and short, it can be developed without affecting the work of the participants.

Corrales et al (2020) conducted a diagnosis of the training needs caused by the post-COVID 19 structural changes for the company Search. The research covered the company's key positions in order to innovate in the products and services they require based on the global disjuncture. The information collection methods used were online surveys and focus groups; in the analysis of results, aspects such as the perception of the job profile and training needs before and after the crisis, the main structural changes, and their impact on the execution of their functions and how the company could contribute to the achievement of the strategic objectives from the customer's perspective, after COVID 19, were evaluated. Finally, two Excel tools were designed, one with the different training topics proposed and the other with the graphs and tables of the information for the analysis of the information for the company and its recommendations for use. The main conclusion of the research was that employees need to develop their skills and knowledge more and more to improve their professional career and the service provided to the customer; so training topics were identified in different areas that aim to increase the quality of service and the development of the company's key employees to improve their skills.

The study conducted for the Costa Rican Penitentiary System had the following objectives:

General objective: Determine the priority training requirements of the Prison System personnel in order to verify the feasibility of satisfying them through the use of MOOCs.

Specific objectives:

- Determine the training requirements of the personnel of the Costa Rican Penitentiary System.
- Establish priority for existing training requirements.
- Characterize at least ten MOOC platforms that offer online training courses.
- Determine which MOOC platforms offer courses to meet the priority training requirements of prison system personnel.

## Method

Based on the objectives set, an exploratory mixed research was carried out in order to identify and prioritize the training needs of the Costa Rican Penitentiary System personnel and to verify whether these could be met through MOOCs. According to the research blog salusplay.com, mixed research (Teddlie and Tashakkori, 2009; Creswell and Plano, 2008; Bergman, 2008), integrative research (Johnson and Onwuegbuzie, 2004), multi-method research (Hunter and Brewer, 2003; Morse, 2003), multiple methods (Johnson, Onwuegbuzie and Turner, 2006), or triangulation studies (Sandelowski, 2003), involves the combination of qualitative and quantitative approaches in a single study, so that the quantitative results of the study can be used to conduct a qualitative analysis, The quantitative results of the study can be used to carry out a qualitative analysis to better understand the phenomenon, or the conclusions of a qualitative study can be applied to a quantitative study, and it is valid to complement one with the other in such a way that the strengths of both types are used, trying to minimize their potential weaknesses. In the research conducted for the Costa Rican Penitentiary System, the quantitative part was the classification of the information, carried out to define and prioritize the training needs of the personnel, while the qualitative part was the characterization of the MOOC platforms in search of courses applicable to the satisfaction of the existing training requirements.

The data were collected through the application of an online questionnaire (https://es.surveymonkey.com/r/6D55W2L), which was sent to 63 employees holding the position of Chief, who were asked for information on the training needs of their employees, classified by the specialty of the position as well as their respective prioritization.

Because it was necessary to achieve a complete diagnosis of the training needs of the personnel, as well as their level of priority, the study did not use a sample and worked with the entire population. It was decided to work with the people who occupy management positions and not directly with the personnel, in order to take advantage of the experience and knowledge that the managers have about the training needs of the personnel for the adequate performance of their work since it is the managers who evaluate the performance of the subordinates and detect the gaps and training needs, based on the results of the work of the employees.

The information collected through the questionnaire sought to characterize the person completing the instrument (position, years of service, and place of work), as well as the collaborators under his/her responsibility (job class and number) to finally collect the training requirements of the collaborators (occupational class, name of the course, level of priority, and number of hours of training required). A questionnaire administered electronically and not an interview was used, considering both the number of people required to participate and their geographic location.

The instruments developed for the research were validated prior to their application by two experts, who assessed the items that made up the instruments. They were asked to qualitatively evaluate their degree of relevance to the object of study as well as their degree of precision and adequacy. Ruiz (2002) refers that "expert judgment" is a procedure used to determine content validity, which consists of asking a group of people to judge an object, an instrument, a teaching material, or to give their opinion related to a specific aspect. In the case of the research conducted, content validation sought to analyze and evaluate the questions posed as well as to check whether the items included measured all the categories or descriptors to be measured. The selection of the experts was based on their background and experience in the field of training in the Costa Rican Penitentiary System. The evaluation modality was individual, with the instruments

being sent to each of the experts who were to respond, without any interaction between them. The observations made by the experts were incorporated into the data collection instruments.

Once the data had been collected through the application of the questionnaire, we proceeded to the quantitative analysis of the information collected, tabulating it in order to generate the training requirements according to the positions for which they were requested as well as the level of priority assigned to each requirement. The tool used to tabulate the data was Microsoft Excel.

In order to verify the feasibility of satisfying the training requirements of the Costa Rican Penitentiary System personnel through the use of MOOCs, after tabulating the information collected through the questionnaire, we proceeded to analyze 33 platforms that offer MOOCs. The criterion for the selection of MOOC platforms was the authors' own construction, based on the consultation on the Internet of sites of platforms of educational institutions in Costa Rica, Latin America, and Spain, which offer MOOCs in Spanish language with content similar to the requested training courses. An analysis of the courses offered in Spanish on the Udemy platform was also incorporated. A content review process was applied to these platforms in which the name of the platform, its URL address, the name of the course, its content, objectives, activities, form of evaluation, methodology, role of the tutor/mediator, course programming, prerequisites, the technological platform used, the design/navigation used, the technical requirement for its use, its usability, the possibility of certification, course duration, and the possibility of following up the student's progress were analyzed.

According to Abela (2002), content analysis is a technique for interpreting materials such as texts, images, or recordings, which, when read and interpreted using techniques to explain and systematize their content, allow us to understand various aspects and phenomena, whether these are quantifiable or unquantifiable indications. The analyst must perform actions adapted to the nature of the material and the problem he is trying to solve. The article indicates that with the emergence of computers at the end of the 50's, software turns the computer into an efficient instrument for data processing, which constitutes the basis for numerous content analysis applications, being Sebeok and Zeps (1958) the pioneers of content analysis using computers; these researchers applied information retrieval routines to analyze popular legends. The author cites that the ability of computers to perform literal rather than numerical analysis has tipped the balance in the application of content analysis as a qualitative research technique.

The information derived from the review of MOOC platforms was the input to determine the feasibility of applying massive open online courses in the training of National Penitentiary System personnel.

## Results

By conducting the research, it was determined that it is feasible to apply the courses offered by MOOC platforms to meet the priority training needs of Costa Rican Prison System personnel. This conclusion is based on the fact that of the 154 courses requested by the people who completed the questionnaire applied, it was possible to locate 74 MOOC courses offered by one of the analyzed platforms. The following is a summary of the results obtained, which were organized according to the objectives to which they respond.

Objective: "Determine the training requirements of Prison System personnel".

This objective sought to determine the training courses, programs or activities that people in management positions considered necessary to improve the performance of the workers in their charge. The people who participated in the research indicated 154 courses, the 6 most requested are shown in Figure 1.

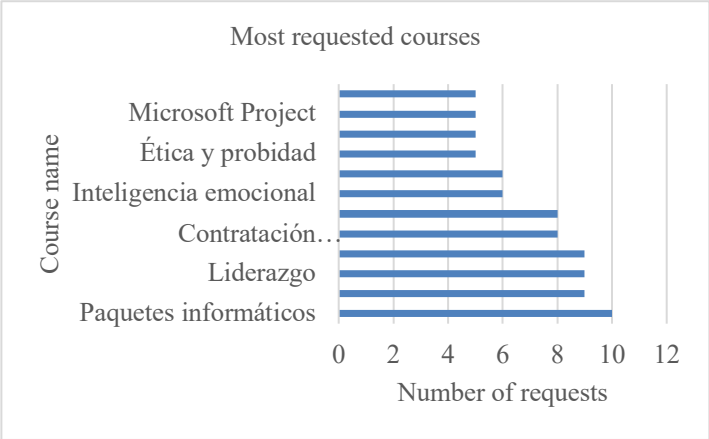


*Figure 1.* Most requested courses.
*Note:* Source: Own elaboration, data taken from the questionnaire applied.

Participants requested courses such as human rights, gender equality, prevention of sexual and workplace harassment, technical subjects, electricity, electronics, technological applications, health, administration, public policy, law, education, statistics, ethics, nutrition, management, soft skills, emotional intelligence, research, kitchen work, LGBTI, leadership, secretarial work and techniques, communication, administrative contracting, weapons handling, warehouse management, inventory management, mechanics, stress management, first aid, psychology-related topics, public relations, conflict resolution, prison systems, search techniques, security, customer service, family therapy, violence, use of time, teamwork, and telecommunications.

For most of the job categories, respondents specified more than one training requirement, with some categories, such as Prison Police, Systems Analysts, Prison Technical Professionals, and Social Work Professionals, for which more than 20 training requirements were indicated, which shows the urgent need for staff training in the institution.

Objective: "To establish the priority for the training requirements determined."

The training requirements indicated by the people who completed the questionnaire while being expressed had to be prioritized to determine which of them were preeminent over the others, with the purpose of seeking their satisfaction through the use of MOOCs. Figure 2 shows the 11 names of the courses that were most mentioned as priority 1 in the questionnaire.

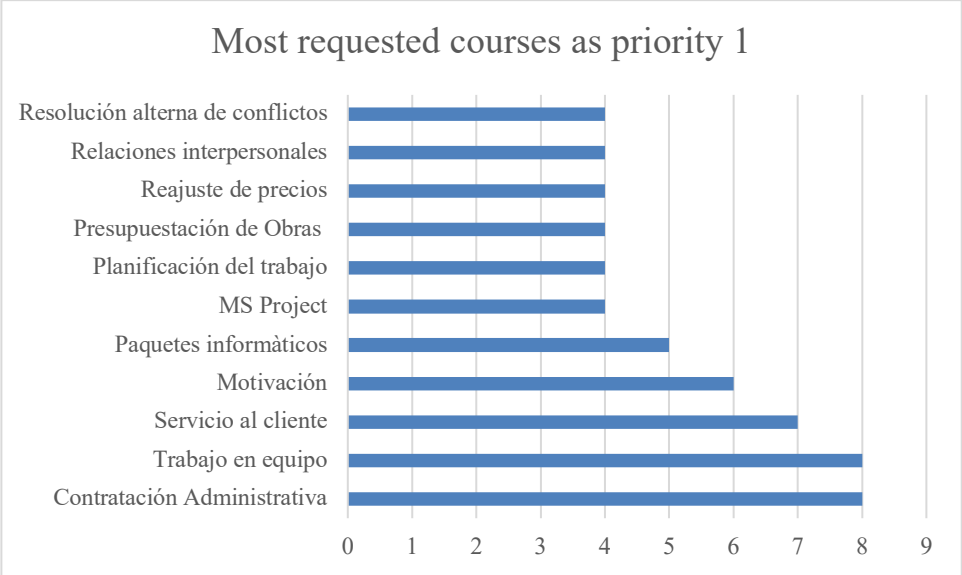


*Figure 2.* Courses most cited as priority 1.
*Note:* Source: Own elaboration, data taken from the questionnaire applied.

For most of the classes defined, more than one course was established as priority 1, a situation that indicates that the lack of financial resources available to train personnel has prevented prison system officials from accessing the training required for the proper performance of their duties.

Objective: Characterize at least ten MOOC platforms that offer online training courses.

An evaluation matrix developed for this purpose was applied to the 33 MOOC platforms selected. Table 1 shows the names of the platforms analyzed, the main topics of the courses reviewed, as well as the number of courses evaluated in each of them.

Table 1
*Summary of analyzed platforms*

| Platform | Institution | Main topic(s) | Number of Courses |
|---|---|---|---|
| UPE | Fundación Omar Dengo | Technology | 68 |
| EdX (Telescope) | Universidad Galileo | Technology | 10 |
| EdX and Open EdX | Ministerio Educación CR | Mathematics | 38 |
| UNED | Universidad Estatal a distancia CR | Pedagogy | 4 |
| INA | Instituto Nacional de Aprendizaje CR | Technology | 76 |
| Coursera | Universidad Autónoma Nacional de México | Technology, Business and Health | 59 |
| Coursera/Ed X/UCC | Universidad Católica de Chile | Technology, Business, Electronics and Engineering | 50 |
| MiriadaX | MCA School | Business | 3 |
| MiriadaX | Universidad Juárez del estado de Durango | Law | 1 |
| MiriadaX | Universidad del país Vasco | Social | 3 |

| | | | |
|---|---|---|---|
| MiriadaX | Universidad Francisco Gavidia San Salvador | Technology | 1 |
| MiriadaX | Instituto Tecnológico Telefónica | Technology | 7 |
| **Platform** | **Institution** | **Main topic(s)** | **Number of Courses** |
| MiriadaX | Banco de desarrollo de América Latina | Public Administration and Law | 9 |
| MiriadaX | Fundación telefónica | Technology | 7 |
| MiriadaX | Universidad de Murcia | Law | 1 |
| MiriadaX | Universidad Anáhuac | Technology | 1 |
| MiriadaX | Corporación Universitaria minuto de Dios | Social | 1 |
| MiriadaX | Universidad Politécnica de Cartagena | Statistics | 2 |
| MiriadaX | Universidad Europea | Law | 1 |
| MiriadaX | Universidad del Norte | Criminology and Business | 2 |
| MiriadaX | Fundación Alimerka | Nutrition | 1 |
| MiriadaX | Universitat Oberta de Catalunya | Technology | 1 |
| MiriadaX | Universidad nacional del Nordeste | Nutrition | 1 |
| MiriadaX | Universitat de Lleida | Social | 1 |
| MiriadaX | Instituto Cervantes | Teaching | 1 |
| MiriadaX | Universidad de Zaragoza | Technology | 2 |
| MiriadaX | Universitat de les Illes Balears | Technology | 1 |
| MiriadaX | Universidad Cooperativa de Colombia | Law and Business | 2 |
| MiriadaX | Universidad de Salamanca | Statistics, Business, Health | 3 |
| MiriadaX | Universidad de Málaga | Business | 2 |
| MiriadaX | Universidad del Rosario | Social | 1 |
| MiriadaX | Universidad de Cantabria | Social and Business | 2 |
| MiriadaX | Universidad Autónoma de Occidente | Education | 1 |
| MiriadaX | Universitas Telefónica | Technology and Business | 4 |
| Udemy | Udemy | Social, Technology and Business | 33 |
| Total | | | 400 |

*Note:* Source: Own elaboration

As part of the findings related to the fulfillment of this objective, it was determined that although the platforms offer MOOCs that can be studied independently as a free course, there are also some that offer specialized programs, professional certificates, Master Tracks certificates, or professional degrees.

In the fulfillment of this objective, there was the limitation of not knowing the instrumental use of other languages by the employees, so it is recommended to future researchers that the questionnaire to be developed for the collection of information should include a query regarding the instrumental use of other languages as this can expand the number of courses and MOOC platforms that can be incorporated into the analysis.

A finding related to this objective is related to the updating of information on MOOC platform courses since the companies or institutions that manage these platforms should strive to keep updated all the information regarding the courses they offer, specifically the information related to the opening date of the course; in the event that this date has already passed, it should indicate the new opening date or period.

Objective: "Determine which MOOC platforms offer courses to meet the priority training requirements of prison system personnel."

To meet this objective, a list of all the courses requested by the people who responded to the questionnaire was taken, as well as the content of the document generated as a result of the review of the platforms in order to determine which of the platforms analyzed offer MOOCs that were requested by those who participated in the research. Figure 3 shows the platforms where the largest number of MOOCs were located.

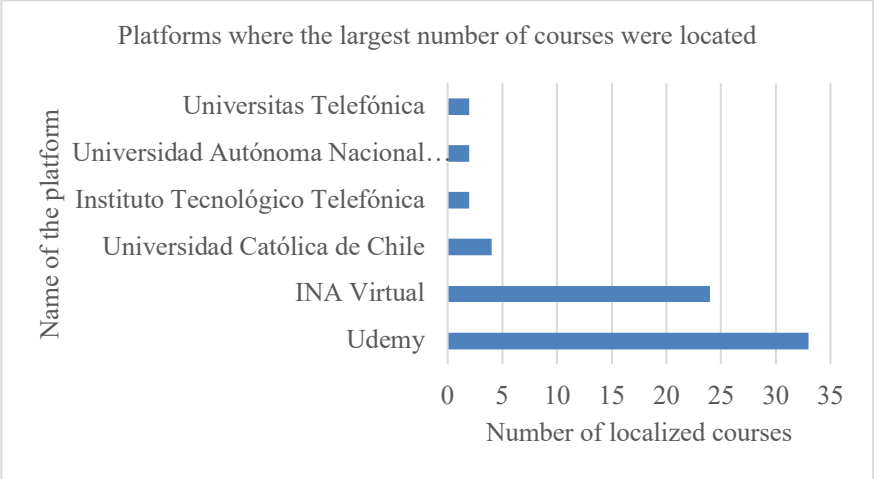


*Figure 3.* Platforms where the largest number of courses were located.
*Note*: Source: Own elaboration, data taken from the platform review document.

As a result of the review carried out by the researchers, it was found that there are other courses on similar topics that can also be used in the training of Prison System personnel; however, since the participants were asked to specify courses, they were not considered in the research. In this regard, a recommendation is made to future researchers, so that in the requirements questionnaire, training topics are requested, and not specific courses or activities since the search by topics can enrich the result of the research.

A finding related to this objective is that there are some courses that, because they are derived from special tools or specific techniques, are not offered on a massive scale. In this case, it is recommended that the Costa Rican Penitentiary System analyze the possibility of offering these courses, either through self-managed virtual platforms or through agreements with other institutions or universities such as the Universidad Estatal a Distancia (UNED), which offers two programs within its academic curriculum that include courses on weapons handling, frisk or search, security, alternative conflict resolution and peace circles. The UNED offers two programs within its academic curriculum that include courses on weapons handling, search and seizure, security, alternative conflict resolution, and peace circles, which can be offered as online or hybrid

courses. These courses can be applied in the training of officials of the Penitentiary System and similar institutions with similar training requirements.

Of the 74 courses located, 63 were classified as priority 1; 2 as priority 2; 1 as priority 5; 1 as priority 12; 4 as priority 17; 1 as priority 18; 1 as priority 19; and 1 as priority 20. Figure 4 shows the distribution of localized courses, according to priority level.

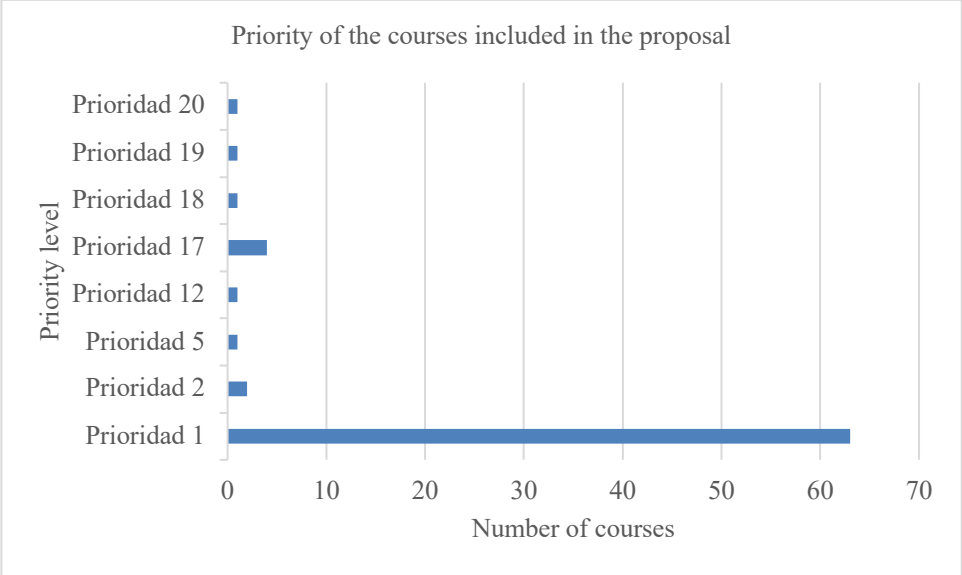


*Figure 4.* Priority of localized courses.
*Note:* Source: Own elaboration, data taken from the questionnaire applied.

The localized courses are applicable to the different types of positions in the Costa Rican penitentiary system. Figure 5 shows the number of courses applicable to the different types of positions.

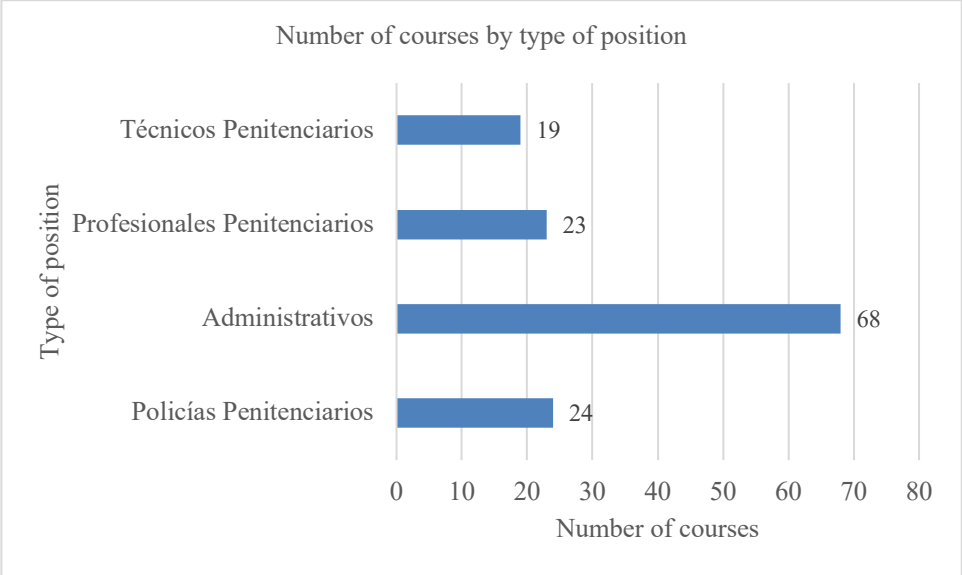


*Figure 5.* Number of courses by type of position.
*Note:* Source: Own elaboration, data taken from the questionnaire applied.

## Discussion and conclusions

Continuing education is an organizational strategy that involves the direction and management of human resources (Pineda, 2007), which in recent years has experienced an increase in the consumption of online training courses, motivated mainly by economic effects (Ponce et al, 2010) or by the effects of the pandemic resulting from COVID-19 (Atiaja and Garcia, 2020), which is why massive open online courses or MOOCs are an option that allows organizations to access international class training, without the need to spend large amounts of money.

Through our research, we detected the priority training needs of the personnel of the Costa Rican Penitentiary System, and with the results obtained, it was determined that it is feasible to apply the online courses offered by MOOC platforms to satisfy them. The data indicate that of the 154 courses requested by the people who completed the questionnaire applied; it was possible to locate 74 MOOCs offered by any of the analyzed platforms. These results are consistent with findings of similar research conducted by Atiaja and Garcia (2020), Ruiz (2019), and Flores (2018); this last research additionally provides results that indicate that a virtual training program would decrease operating costs and related times.

Considering that according to a study conducted by the Colombian University Observatory magazine (2020) as a result of the new reality that society has assumed in the face of the current health situation that is being experienced worldwide, product of the pandemic caused by COVID-19, virtuality will be the big winner; there is a trend towards the disappearance of face-to-face or semi-presential education courses, so that education at the corporate level should privilege institutions that demonstrate the best mix between virtualization and expert resumes.

As quoted by Mora (2019), "The constant change in society, in cultural, economic, and political terms, establishes different ways of educating the population and the birth of variable and dynamic educational models." This is why it is considered that both public and private organizations are opting for training programs based on platforms that develop and manage virtual courses, which are gradually replacing the face-to-face form of training, driving a radical change in the way people are educated and trained.

The research conducted shows that the Costa Rican Prison System has the possibility of migrating its traditional classroom training model to a virtual one, which will allow it to meet its training needs, making the most of the MOOC market offer.

The diagnosis of training needs developed through our research, allowed us to identify the knowledge, skills, and aptitudes required by officials of the Costa Rican Penitentiary System to effectively perform their duties. This diagnosis served as the basis for the development of the research in which the feasibility of using MOOCs to meet the training requirements of officials of the Costa Rican Penitentiary System was determined in such a way that it meets the criteria of quality, effectiveness, low cost, eliminating the need for students to physically move to a specific location. According to Amaya and Valles (2015), the accelerated growth that technology has experienced in recent years has modified the teaching-learning process, where resources such as MOOCs offer the possibility of sharing information and acquiring new knowledge, without the need to physically go to a classroom, attending students from all over the world virtually, so that people can prepare for the changing labor market. The use of MOOCs for personnel training promotes continuous learning, democratizing access to knowledge because through their publication it is possible for students to receive the knowledge imparted by

prestigious universities or technical or higher education institutions, regardless of their geographic location.

The background information gathered for the elaboration of the research shows that the use of MOOCs for personnel training is a practice that has been implemented by several organizations, both public and private, which has yielded positive results in terms of costs and time. Mendoza, Álvarez, and Muñoz (2014) cite in their research work entitled, "MOOCs based on competencies and used as training tools: the Vagones de Ciencia case" that the popularity and impact of MOOCs is based on the fact that they offer massive and free education, using the advantages provided by the virtual spaces enabled by the use of the Internet, promoting social learning generated by the community of course participants. For his part, Novillo (2018) in his Master's thesis entitled "Design and implementation of a MOOC, applying the PACIE methodology, for the development of new pedagogical strategies with the use of ICT in teaching practice and optimize the teaching-learning process," points out that MOOCs constitute a suitable resource for the development of new pedagogical strategies, promoting innovative ideas through the application of educational methodologies that fit different types of learning. Considering that the results of the research conducted in the Costa Rican Penitentiary System indicate the existence of a large number and variety of training requirements, the application of MOOCs to satisfy them is not only a feasible situation but also desirable and convenient, both from the perspective of the official and from the institutional perspective since virtuality reduces the gaps that arise from the geographical location of people or the limited availability of time and resources required for their displacement. The availability of MOOCs developed by external institutions offers the advantage that the Costa Rican Penitentiary System is not required to invest time, effort, and resources in the assembly of training courses that have been published by specialized institutions, with extensive experience and professors of recognized trajectory in the topics of the courses they publish. The application of MOOCs in staff training will allow the Penitentiary System to strengthen its management capacity because as stated in the Adecco company blog (2020), "Continuous staff training allows employees to plan, improve, and carry out their activities more efficiently in collaboration with the other members of the organization." A properly trained work group is a motivated group, where people maintain high morale, which translates into a decrease in staff turnover as employees feel valued and important to the organization. Adequate training empowers people for a better performance of their work, helping them to solve problems, whether simple or complex, daily or singular, which reduces the need to establish schemes based on supervision and control because a trained employee is capable of self-management, improving the stability and flexibility of the organization through the development of new skills. Training also reduces the occurrence of work accidents since trained personnel will perform their work in a better way and with greater knowledge of methods, techniques, and standards that enrich personal and group management, allowing the introduction of improvements in processes and structures, which over time become knowledge and experiences that are added to the pool of organizational knowledge, promoting the evolution and continuous improvement of companies or institutions.

From the results of the research, the opportunity arises to conduct a study on the effect of the lack of training in the Costa Rican Penitentiary System since this factor can affect performance, productivity, costs, motivation, staff turnover, and occupational accidents, but, above all, the worst part is borne by the management of organizational knowledge since it prevents the organization from being able to self-analyze and improve itself, following the best practices at international level and the latest market trends.

Finally, we would like to state that according to the information collected in our research, MOOC promoters should focus their attention on three fundamental aspects: student dropout, the financial sustainability of the MOOC business model, and finally the quality of MOOCs. Regarding student attrition, the dropout rate in MOOCs is very high, being close to 90%, according to studies by several authors. Armstrong (2014) reported that only 4% of students registered in a MOOC in Coursera completed their courses. Onah, Sinclair, and Boyatt (2014) place the dropout rate at 87%, while Rivard (2013) reported a 90% dropout rate. Campbell, DeBlois, and Oblinger, (2007) propose that despite the high dropout rate of MOOCs, the amount of data that emerges from these courses, resulting from the participation of learners, who perform some of the course evaluation tasks, allows to generate analytics to know how people learn (Learning Analytics). Gee (2012) proposes that high dropout rates may not be a major concern, but discovering why and at what stage students drop out could help design future quality metrics.

Regarding the financial sustainability of MOOCs, several authors point out the need for MOOC providers to establish a business model that allows them to maintain massive open online courses that respond to the demand generated by the proliferation of MOOCs. In this regard, some platforms such as Coursera, edX, and Udacity raise foreign exchange and receive donations from universities and foundations, thus managing to maintain a sustainable MOOC model. Dellarocas & Van Alstyne, (2013) found that some MOOC providers use certifications to monetize these courses in such a way that a learner can enroll a course and successfully complete it for free; but to obtain a certification issued by some recognized university, the learner must pay a fee, which varies depending on the course. Other institutions, such as the University of Washington, have tested a hybrid model, that is, a free MOOC offered at the same time as its paid version, which had a more rigorous academic model, allowing the learner to opt for university credits. Another way of attracting foreign exchange through MOOCs is through recruitment programs that use trainee databases to identify potential employees for companies.

According to Hayes (2015), the real revolution of MOOCs is the questions related to learning in a global society, in addition to the considerations of improving the quality and assurance of learning that these courses offer. Because MOOCs can range from carrying free university courses to simple interest in testing the methodology, it is difficult to discuss their quality in general terms as this will depend on the type of MOOC being evaluated. Downes (2016) states that the success of a MOOC is defined by the process rather than the results, considering this type of courses as a vehicle to discover new experiences due to the fact that each learner has their own objectives and success criteria, the quality of the course measured in terms of success will depend on each learner, reaching their own objectives. Yuan and Powell (2013) also propose that issues of quality, sustainability, pedagogy, completion rates, and credit awarding in MOOCs are of great concern to higher education providers and need to be addressed to ensure the quality of these courses.

Considering that self-regulated learning is one of the key competencies for the individual throughout life (Bartolomé and Steffens, 2015), this involves cognitive, affective, motivational, and behavioral components that provide the person with the ability to adjust their goals and actions to achieve the desired results depending on the conditions of the environment (Zeidner et al, 2000). It is necessary that MOOC providers analyze the market niche to which they are orienting their services in order to adapt them to the needs, interests, and particularities of their target audience, enhancing the benefits offered by massive open online courses in order to motivate learners not only to enroll

but also to successfully complete the MOOCs in which they register, thus seeking to increase the number of positive experiences, which encourage a greater number of organizations and learners to opt for MOOCs for their continuing education, whether technical or professional.

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**Receipt date:** 10/26/2021

**Revision date:** 01/31/2022

**Acceptance date:** 05/26/2022

**PROJECT, DESIGN AND MANAGEMENT**

**ISSN: 2683-1597**

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

Toledo, M. A. (2022). Seguimiento y control de ganado vacuno mediante geoposicionamiento. *Project, Design and Management,4*(1), 91-113. doi: 10.35992/pdm.4vi1.828

# MONITORING AND CONTROL OF CATTLE BY GEOPOSITIONING

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**Abstract.** The development of this research work called *monitoring and control of cattle by geopositioning*, whose priority line is innovation and technology and is of the applied type. With it, it will be possible to develop a prototype that will allow determining the location of the cattle in real time. It allows receiving location coordinates in real time and then sending them through the cellular network to an Internet of Things web platform that operates with this information and feeds different widgets in which the location of the cattle can be observed. To achieve this, a Global Positioning System is used, whose objective is to determine the spatial coordinates of points with respect to a world reference system. The system is based on the Arduino board connected to a SIM808 module that offers GPS technology and allows the satellites to request positioning coordinates. In the future, it is estimated that all farmers must have an animal control system, because it is essential to monitor and control in real time, to know the location, combat theft and control the health of the same. The methodology used for the development of the system is that of prototyping.

**Keywords:** Geopositioning, IoT, Cattle, Prototype.

# SEGUIMIENTO Y CONTROL DE GANADO VACUNO MEDIANTE GEOPOSICIONAMIENTO

**Resumen.** El desarrollo del presente trabajo de investigación denominado *seguimiento y control de ganado vacuno mediante geoposicionamiento*, cuya línea prioritaria es innovación y tecnología y es del tipo aplicada. Con el mismo se logró desarrollar, un prototipo que permite determinar la ubicación en tiempo real el ganado vacuno. Permite recibir coordenadas de ubicación en tiempo real para luego enviarlas mediante la red celular a una plataforma web de Internet de las Cosas que opera con esta información y alimenta diferentes widgets en los cuales se puede observar la ubicación del ganado. Para lograr esto se utiliza un Sistema de Posicionamiento Global, cuyo objetivo es determinar las coordenadas espaciales de puntos respecto de un sistema de referencia mundial. El sistema está basado en la placa Arduino conectado

a un módulo SIM808 que ofrece la tecnología GPS y permite solicitar a los satélites coordenadas de posicionamiento. En un futuro, se estima, que todas las ganaderas deberían contar con un sistema de control de animales, debido a que es primordial realizar seguimiento y control en tiempo real, para conocer la ubicación, combatir el robo y controlar la salud del mismo. La metodología utilizada para el desarrollo del sistema es la del prototipado.

**Palabras clave:** Geoposicionamiento, IoT, Ganado, Prototipo.

## Introduction

Argentina has historically been an agricultural-livestock farming country and, given its size and production volumes, it is considered one of the world's major food suppliers. In recent years, among other things, due to commodity prices (firstly, the price of soybeans and secondly, the price of wheat) and political factors, livestock farming has lost ground to agriculture. (Agrositio, 2008)

The Argentine northeast (NEA) is made up of the provinces of Corrientes, Misiones, Chaco, and Formosa in their entirety and part of the provinces of Entre Ríos and Santa Fe, which share agroeconomic characteristics that give the region its own identity. It has 19.46 million heads of cattle, which represent 40% of the national cattle stock, according to the first vaccination campaign of 2010 by SENASA. In order of importance, Santa Fe has 6.03 million heads, Corrientes 4.87 million, Entre Ríos 3.98 million, Chaco 2.38 million, Formosa 1.79 million, and finally Misiones only 410 thousand heads. (Acosta, F. and others, 2012).

Livestock producers are grouped into strata according to the amount of cattle they own, according to SENASA (2010). In this way, the provinces of Santa Fe with 44%, Misiones with 35% of cattle owned by the smallest producers (owning up to 100 heads), and Corrientes with 19% of cattle owned by the largest establishments (owning more than 5,000 heads).

According to INTA (2015), there is clear evidence that livestock production in the Province of Formosa has grown quantitatively in recent decades. There are several causes that drove this local productive intensification. In particular, the process of agriculturization that the country has been undergoing for more than a decade, which led to the growth of livestock in regions such as the NOA and NEA. Thus, livestock farming in Formosa, as in the rest of the country, has undergone structural and geographical changes as a consequence of the transformation of the agricultural sector.

In a long-term view, regardless of short-term cycles, two stages can be identified in the evolution of the cattle stock in Formosa during the last 12 years. The first one between 2003 and 2008 in which there was a significant increase in the stock, which expanded at a cumulative annual rate of 5%. And in the second stage between 2009 and 2015, there was no notable rate of change in the stock, but after a slight drop in the stock, a new phase of retention began to the point that in 2013 it reached levels higher than those recorded in 2008. Therefore, it could be argued that the minimum values reached during 2008 constituted a floor from which the Formoseño livestock cycle evolved in recent years; the data released by INTA in 2015.

However, "cattle rustling" continues to be in our country one of the scourges that has hit the livestock sector the most, known in the country jargon as "cattle rustling"; it is a criminal behavior difficult to control. To this, we must add the clandestine slaughter that implies a risk to human and animal health, with the corresponding tax evasion, transport, and marketing without compliance with sanitary and bromatological standards,

seriously compromising the human and animal health aspect, with serious risks of the spread of various diseases.

This criminal activity is favored by the large rural extensions of our country and our province, which often prevent the prevention of an adequate control in the care of the property of livestock, cattle, etc., added to the deficiencies in the infrastructure of the rural police of the country and the legislation that ordered a greater repressive action, established in Law No. 25,890 of the Criminal Code of the Province of Formosa.

The loss of cattle by cattle farmers in the Province of Formosa is a very important issue to solve, currently the same have no way to effectively control the location of their animals and can only hire people to take care of their cattle, but that implies a high economic cost. (AM990formosa, 2017)

According to the president of the Formosa Rural Society, Carlos Montoya, cattle rustling has increased in the last year in the border zone, and he expressed the concern of the farmers about the violence and aggressiveness of the rustlers. (Agrositio, 2008)

This is evidenced in the note made to a cattle rancher located to the north of the capital of Formosa, who commented with much anguish, the serious damage caused to the economy and work, the sustained and increasingly sophisticated action of cattle rustlers. Cattle rustling depredates the livestock economy of the province and hacks the labor source. (Panaroma Regional, 2018)

According to members of the Livestock Association of Formosa, 80% of animal losses in the Province of Formosa are due to livestock theft, 15% to strays in other fields, and 5% to diseases; for this reason, they proposed the feasibility of using ICTs to control and know the location of their animals at a given time.

Nowadays, technologies are migrating to all fields of the economy, providing innovation and constant progress. More and more we find ourselves in a highly interconnected environment, where the goal is the development and improvement of current systems, seeking greater viability and feasibility in the processes.

From this need arises the idea of the present research project in order to satisfy this basic need for farmers using new technologies combining the concepts of Hardware and Free Software, Internet of Things, and satellite geopositioning.

Based on the above, a prototype was developed to determine the real-time location of cattle. The system allows to receive location coordinates in real time and then send them via satellite signal to a web platform of Internet of Things (IOT) that operates with this information and feeds different widgets in which you can see the location of cattle, date and time of the same.

To achieve this, a global positioning system (GPS) will be used, whose objective is to determine the spatial coordinates of points with respect to a world reference system.

According to the Bankinter Foundation of Innovation, the Internet of Things or IoT is based on interlinking everyday objects with the Internet, thus making it easier to obtain and manage information. This is what the well-known sensor networks consist of, which are made up of a specific number of devices and whose data goes to a coordinating node or router and from there to a web server where it is possible to store and maintain the most relevant information.

This type of technologies is not only being seen in the field of intercommunication and the military; it is also being seen how this type of aspects have migrated to sectors in which very little was believed to be necessary, such as the field of agronomy in all its subdivisions. This field still continues to be managed with little technological affection in the Province of Formosa.

The general objective of the research was to determine the applicability of a technological system of free hardware and software for the monitoring of cattle in the province of Formosa in the period 2020 - 2021.

And its specific objectives were:

- Analyze alternatives for the control and monitoring of cattle location.
- Develop the prototype and interface for the tracking system.
- Simulate the circuit of the device to verify the proper functioning of the prototype.

## Frame of reference

For the elaboration of this project, a compilation of several sources of bibliographic research has been carried out, such as digital repositories of several universities, scientific articles, scientific journals, etc., in search of topics similar to the proposed one, which have developed works that are essential for the elaboration of this research.

In 2013, Ángel René Canché UC and Jonathan Ismael Mukul Chi developed a "LocaPet. Satellite Locator for Pets," where they describe the development of a system that is responsible for monitoring a pet within a specific area. The hardware used in this system consists of an Arduino UNO 328 board model MIC-06664, GPS GY-GPS6MV1 with GPS NEO-6M chip, GSM/GPRS SIM900 board model WGW-06633. The software used is open source using the Arduino platform and AT codes. This system issues a text message alert with the geographic location, time and date that is sent to the owner in case the pet leaves the indicated area for a longer time than the established time, which allows to know the location of the pet anywhere as long as there is GSM cellular network coverage.

In 2015, Ezequiel Gorandi, Nicolás Clemares, and Andrés Moltoni developed a "Collar with GPS technology for animal monitoring," where such system allows obtaining the instantaneous coordinates of the position and communicates through the NMEA 0183 protocol, with an 8-bit microcontroller to process and store the information in non-volatile memory. the programming language used is Python and such information is uploaded to a server and can be accessed through a web application in which the times between samples can be modified. This system was used in cattle, goats, sheep, and also in sheepdogs.

In 2016, Carlos Andrade Parreño developed the "Design and implementation of a client-server system for sending position and vital signs of pets on mobile devices on the Arduino platform." This project is based on the development of a prototype that prevents the loss of pets, sending vital signs and location through a hardware that is located on the chest of the animal with the help of a harness; this sends information to a web server and database, which are processed and stored for display on a mobile device or web interface. The hardware used consists of an Arduino Uno board, SIM Module 908C, Accelerometer Transducer Module MMA7361, Infrared Temperature Sensor MLX90614. The software for the development of the Android application is done using Java language and, in certain parts, makes use of XML language, Arduino language.

In 2016, Guido Buscetti Castro, Matías Prieto, Joaquín Muguerza, and Martín Ríos resumed a project they started at the university: "Do something to prevent cattle theft," investigating they came to the conclusion that it was necessary to know "what was happening to the animal when it is about to get sick or when it is going into rutting, all very important data for the producer." Late last year, they designed a working prototype of a collar that collects data and began testing it in partnership with the Veterinary School of the Universidad Nacional de La Plata. "The hardware connects to the Internet and sends

the information to a platform capable of alerting the producer when something happens to the animal that requires action on his part."

The development is important because it allows, through early detection, to help the producer to save a lot of money in drugs or even to avoid the slaughter of the animal. In addition, through the detection of estrus, whose alert is sent via SMS, the work of the field person is simplified and allows optimizing the short window of time to inseminate the animals.

The unstoppable advance of the Internet has had a radical impact on the economy and society of the 21st century. The convergence of Information and Communication Technologies has transformed the traditional Internet into the Internet of Things (IoT), to such an extent that it has managed to insert itself into the productive system. The result in industry has been a new organizational model and a disruptive change that has been called the "fourth industrial revolution" or "Industry 4.0"; a term coined by the German government to describe the Smart Factory, i.e., "a vision of computerized manufacturing with all processes interconnected by IoT" (Romero et al., 2017).

Based on the problem of the loss of cattle by farmers in the Province of Formosa, which needs a prompt response, this research aims to provide a quick solution through an electronic device located in the caravans of cows, using the concepts of the Internet of Things, geopositioning, and hardware technologies and free software.

According to Karen Rose, Scott Eldridge, Lyman Chapin (2015), the concept of the Internet of Things is an emerging topic of technical, social, and economic importance. Consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects are now being combined with Internet connectivity and powerful data analytics capabilities that promise to transform the way we work, live, and play. Projections of the impact of the IoT on the Internet and the economy are impressive: some anticipate that by 2025 there will be as many as 100 billion IoT-connected devices.

In general, the term Internet of Things refers to scenarios in which network connectivity and computing power are extended to objects, sensors, and everyday items that are not typically considered computers, allowing these devices to generate, exchange, and consume data with minimal human intervention. However, there is no single, universal definition. (Karen Rose, Scott Eldridge, Lyman Chapin, 2015)

According to Ghio M. Gina (2008), the Global Positioning System or GPS, although its correct name is NAVSTAR-GPS1, is a global satellite navigation system that allows the position of an object, person, vehicle, or ship to be determined worldwide. We can reach an accuracy of up to centimeters, using differential GPS, but the usual is a few meters.

GPS operates through a network of 27 satellites (24 operational and 3 backup satellites) in orbit, 20,200 km above the globe, with synchronized trajectories to cover the entire surface of the Earth. When a position is to be determined, the receiver used for this purpose automatically locates at least three satellites in the network, from which it receives signals indicating the position and clock of each of them. Based on these signals, the device synchronizes the Positioning System clock and calculates the delay of the signals, i.e. the distance to the satellite. By "triangulation," the three satellites calculate the position where the GPS is located. Triangulation, in the case of the Global Positioning System, is based on determining the distance of each satellite from the measuring point. Knowing the distances, the relative position with respect to the three satellites is easily determined. Knowing also the coordinates or position of each one of them by the signal they emit, the absolute position or real coordinates of the point and measurement is

obtained. An extreme accuracy is also achieved in the GPS clock, similar to that of the atomic clocks carried on board each of the satellites. (Ghio M. Gina, 2008).

When we talk about free hardware, we refer to the freedom that exists when using any device along with all its documentation. According to Delgado (2018), hardware is considered free when all the information of its hardware, designs, measurements, and tools used for the creation of such devices are shared publicly, thus helping developers so that they can improve designs and contribute much more to this type of projects. (Delgado, 2018).

Free software refers to the freedom of users to modify, copy, run, study, distribute, and improve the software. However, according to the Free Software Foundation "*a program is considered free software if users have access to the four essential freedoms, such as:*

- Freedom to run the program as the user wishes.
- Freedom to study how the program works and modify it according to the user's needs.
- Freedom to distribute copies of the software to others.
- Freedom to distribute copies of improved versions from third parties."

## Methodology

Based on the aforementioned concepts, the project was divided into stages taking into account the objectives proposed at present.

The Prototype Model will be used for the design of the device and the development of the software, and the Kanban agile methodology will be used for the fulfillment of the stages of the project.

According to Sommerville (2011): "*System prototyping, where a version of the system or a part of the system is quickly developed to test customer requirements and the feasibility of some design decisions. This supports the avoidance of change by allowing users to experiment with the system before delivery to refine their requirements. As a result, the number of post-delivery requirements change proposals is likely to be reduced.* " (Sommerville, 2011, p. 44)

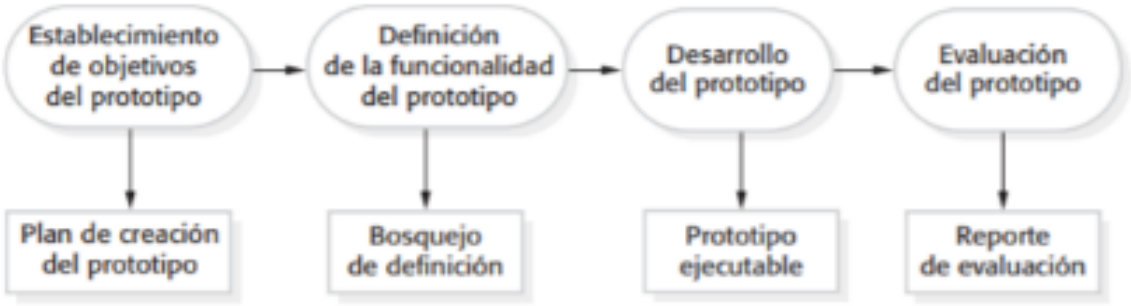


*Figure 1.* Prototype development process
*Note:* Source: (Sommerville, 2005, p. 375)

During the development, the 808 SIM module was assembled to the Arduino board, and then the programming of these boards was carried out. Different tests were carried out until the system worked correctly.

The final stage was the evaluation of the prototype, where the objectives established at the beginning were used to obtain an evaluation plan; this plan consisted of the following:

- Perform animal walk tests with the GPS configured and working.
- Control through the IoT platform the data sent by our prototype in real time.
- Once the run has been completed, check the values obtained in order to define the prototype performance and discover errors and omissions in the prototype.

***System Definition and Development***

In this stage, the first step was the definition of the requirements and the risk analysis, then it is explained how the selection of the motherboard and the modules necessary to carry out the development of the prototype and achieve that it meets the objectives of the project was carried out, the characteristics of the IDE for software development, necessary to carry out the programming of the motherboard, are detailed.

The system proposed in this research work is based on a prototype developed in free hardware and software, more precisely based on the Arduino UNO board as the central core, which will work together with external modules such as the SIM808 shield, which will allow, from the integrated functionalities of GSM, GPRS, and GPS, to obtain the necessary data to carry out the periodic identification of the location of a fleet of vehicles, to see the routes taken by them, and to know in real time their location, direction, and speed.

***System requirements***

Regarding the elicitation of requirements, these were established from interviews, but since this is a project that uses the prototyping methodology, these requirements can be modified at any stage of development, as well as new ones can be added.

The use of this methodology allows to present to the users progress in a way that allows them to see the operation and its implication in the required activities, as well as to find strong and weak aspects in the system since they are the ones who are going to use it on a daily basis.

The initial requirements obtained from the analysis of the information obtained in the interview for the system are detailed below:

- The GPS system must periodically request information from the satellites about their positional coordinates.
- The data delivered by the satellite must be sent to a web server.
- The data sent must be used by a web platform in order to represent the real position of the cell phone on the map.

These requirements were modified by testing the prototype and the following changes were obtained:

- The GPS system must periodically request information from the satellites, such as positioning coordinates (longitude, latitude, altitude), direction, speed, date, and time.
- The data sent must be used by an IoT platform, which can process the data and display its values in different widget (add to glossary).
- This platform must be able to show a history of the routes taken.

### *Choosing the right hardware*

Different alternatives were analyzed, which are offered by the market in relation to the free programming hardware. These options were compared taking into account their characteristics and performance, with respect to the needs presented by this project.

## Different alternatives in free hardware technologies

For the selection and final choice of the hardware used for this project, the main characteristics of different free hardware currently on the market were investigated, taking into account the components, their connections, their performance, and cost.

The following are the different boards analyzed with their corresponding characteristics, functionalities, and market value:

### *Raspberry pi*

Raspberry Pi is a miniature marvel, containing within it significant computing power in a size no larger than a credit card. (Upton, Halfacree, 2016, p. 2)

The processor inside the Raspberry Pi is a Broadcom BCM2835 system-on-chip (SoC) multimedia processor. This means that most of the system components, including the central processing unit and graphics unit along with audio and communications hardware, are integrated within that single hidden component located just below the 256 MB memory chip in the center of the board. (Upton, Halfacree, 2016, p. 6)

It is not just the design of the SoC that makes the BCM2835 different from the processor in your PC or laptop, what also makes it different is that it uses a different Instruction Set Architecture (ISA), known as ARM. (Upton, Halfacree, 2016, p. 6)

Developed by Acorn Computers years ago in the late 1980s, the ARM architecture is relatively little known in the desktop world. Where it excels, however, is in mobile devices: the phone in your pocket is almost certain to have at least one ARM-based processing core hidden inside.

The combination of RISC (Simple Reduced Instruction Set) architecture and its low power consumption make it the perfect choice against desktop computer chips that demand high power consumption and CISC (Complex Instruction Set) architectures. (Upton, Halfacree, 2016, p. 6)

This, however, means that Raspberry Pi is not compatible with traditional PC software. Most software for desktop and laptop computers is built with the x86 instruction set architecture in mind, present in processors such as AMD, Intel, and VIA. Consequently, this software does not run on the Raspberry Pi, which is based on the ARM architecture. (Upton, Halfacree, 2016, p. 7)

Raspberry Pi is designed to run the operating system called GNU/Linux. Unlike Windows or OS X, Linux is open source, this means that it is possible to download the complete source code of the operating system and make any changes you want, nothing is hidden, and all changes made are publicly visible.

This spirit of open-source development has allowed Linux to quickly be modified to be able to run on the Raspberry Pi, a process known as porting, several versions of Linux (known as distributions) have been ported to the Raspberry Pi's BCM2835 chip, including Debian, Fedora Remix, and Arch Linux. (Upton, Halfacree, 2016, p. 7)

***BeagleBoard***

Beagles are small open hardware, open software computers that can be connected to whatever you have around the house. (https://uk.farnell.com/b/beagleboard)

Beagles mean big functionality in small packages because these small PCs can be used for all kinds of applications and can handle many of the same tasks as a desktop PC. (https://uk.farnell.com/b/beagleboard)

They are tiny, affordable, and open source for Android, Ubuntu, and different versions of Linux at your fingertips, of high performance and low power consumption.

The Beagle family's primary goal is to help students learn programming and developers to produce faster without excessive noise and expense. (https://uk.farnell.com/b/beagleboard)

The main characteristics of this plate are as follows:

The BeagleBoard is USB powered and features a 720 MHz ARM Cortex-A8 OMAP3530 processor, NEON and VFP extensions for additional acceleration, high resolution video, and the ability to stream with a portable media player, allowing you to work with all the functionality of a laptop in one small package. (https://beagleboard.org/beagleboard)

The variety of connectivity presented by the board is as follows:

- USB 2.0 port on the move (OTG)
- Connect standard peripherals to USB using any of the following:
    - One mini-A to standard A cable adapter
    - DVI-D using an HDMI to DVI-D adapter
    - MMC / SD / SDIO connector allows for a complete desktop experience.

***Intel***

Intel has designed two models of boards, the Galileo® and the Édison® for free hardware and software projects, but currently it has been discontinued in its development, there are other kits, but due to the costs they are not applied. Below, more technical information of these boards is given.

***Intel Galileo***

The second-generation Intel Galileo board provides a unique board controller for the maker community, students and professional developers. Based on the Intel Quark SoC X1000, a 32-bit Intel Pentium processor class system on a chip (SoC), the original Intel processor and native input/output capabilities of The Intel Galileo (Gen 2) board offers full function for a wide range of Arduino-certified applications and designed to be hardware and software pin-compatible with a wide range of Arduino Uno R3 shields.

The Intel Galileo Gen 2 board also offers a simpler and more cost-effective development environment compared to Intel Atom processor and Intel Core processor-based designs.

They use the Arduino software development environment to create programs for Galileo called "sketches."

### *Intel® Edison*

The Intel Edison development platform is designed to reduce barriers to entry for a range of inventors, entrepreneurs, and consumer product designers to rapidly prototype and produce Internet of Things (IoT) and wearable computing products.

The Intel Edison compute module is designed for use with custom printed circuit boards.

### *Arduino*

First of all, it is important to define that when we talk about Arduino. We are talking about three things:

- A free hardware board that incorporates a reprogrammable microcontroller and a series of socket pins (which are internally linked to the input/output pins of the microcontroller) that allow different sensors and actuators to be connected there in a very simple and convenient way. (Torrente Artero, 2013, p. 65).
- A software (more specifically, a "development environment") free, complimentary, and multiplatform (since it works on Linux, MacOS, and Windows) that we must install on our computer and that allows us to write, verify, and save ("load") in the memory of the microcontroller of the Arduino board the set of instructions that we want it to start executing. That is to say, it allows us to program it.

The standard way to connect our computer with the Arduino board to send and record these instructions is through a simple USB cable because most Arduino boards incorporate a connector of this type. (Torrente Artero, 2013, p. 66).

- A free programming language, "programming language" means any artificial language designed to express instructions (following certain syntactic rules) that can be carried out by machines.

Specifically, within the Arduino language, we find elements similar to many other existing programming languages (such as conditional blocks, repetitive blocks, variables, etc.), as well as different commands - also called "commands" or "functions" - that allow us to specify in a consistent and error-free way the exact instructions that we want to program in the microcontroller of the board. We write these commands using the Arduino development environment. (Torrente Artero, 2013, p. 66)

There is a wide variety of Arduino boards, but the one taken for this research is the Arduino UNO R3, which uses the ATmega328 microcontroller, in addition to all the features of the previous boards. The Arduino Uno uses the ATmega16U2 for USB handling instead of the 8U2; this allows faster transfer rates and more memory. No drivers are needed for Linux or Mac.

SDA and SCL pins are added near the AREF; moreover, there are two new pins near the RESET pin, one is the IOREF, which allows the shields to adapt to the voltage provided by the board, the other pin is not connected and is reserved for future purposes. The board works with all existing shields and will be able to adapt to new shields using these additional pins.

The open-source IDE can be downloaded free of charge and is currently available for Mac OS X, Windows, and Linux.

The characteristics of the plate are:

- ATmega328 microcontroller.

- Input voltage 7-12V.
- 14 digital I/O pins (6 PWM outputs).
- 6 analog inputs.
- 32k Flash memory.
- 16MHz clock speed.

***Technical specification of the hardware used***

The focus of the project is oriented towards the Arduino UNO so the rest of the hardware or modules were selected based on this development board.

Previously we detailed the characteristics of the Arduino board, for this reason we will now provide specific information about the module that is integrated to the motherboard to achieve the functionality required for this project, it is the eMGing SIM808 shield.

***eMGing SIM808 Shield***

The eMGing SIM808 shield is a very useful board for this project because it allows GSM, GPS, and GPRS connectivity by integrating multiple modules on a single shield, making it very easy to implement on our Arduino UNO motherboard.

## Results

As for the results, several tests were carried out on the device; as a first step, a 12-volt, 2 Amp power source was connected to the Arduino UNO either with a charger or with a portable battery; it must be ensured that it turns on correctly and starts sending data to the web platform.

Once it has been verified that the device has been turned on correctly, it is enabled to perform the pertinent tests in a simple route in the field and observe how the route we are traveling is drawn on the map in real time.

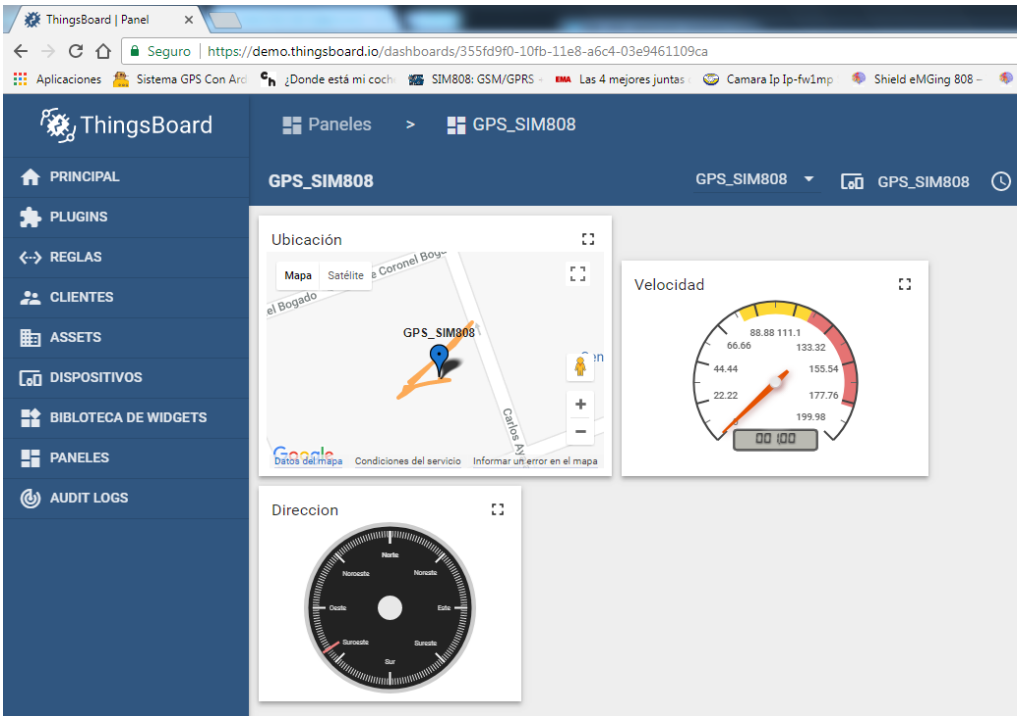


*Figure 2.* Simulation.
*Note:* Source: Own elaboration.

As can be seen in the illustration above, the map exceeded all expectations and was able to collect really accurate data on the trails traveled; in addition, the speed and direction data were considerably acceptable, thus fulfilling the objectives of this project.

In general, the device can be installed on any type of animal to be monitored and the results can be observed on the ThingsBoard web platform, thus obtaining precise control over them.

In summary, the GPS tracker was programmed to send data directly to ThingsBoard via HTTP POST requests, and we managed the data in a dashboard, where multiple devices and panels can be added, each with multiple widgets that provide a very good visual impression and have many customization options.

ThingsBoard has proven to be a very powerful tool for observing IoT data, it has a very simple interface, as is its configuration, allowing a simple and fast connection for devices.

## Conclusions

The general objective of this research consisted in the development of a system capable of requesting and receiving positioning coordinates from satellites dedicated to global geo-positioning and being able to send the information obtained to a WEB platform to be able to visualize that data there, to track the animal, and try to prevent its theft. This was carried out through the implementation of free programming hardware and software, the elements used were the Arduino UNO, the SIM808 shield, the Arduino development environment, and the ThingsBoard internet of things platform.

The Arduino UNO R3 is an open-source physical computing platform based on a simple input/output board that has its own development IDE, which can be integrated with different modules to perform an infinite number of functions and actions.

We used, together with the Arduino UNO, the SIM808 shield developed by an Argentine company, which has integrated on its board the GSM, GPRS, and GPS modules necessary to meet the objectives proposed for this research. This board is designed to be perfectly embedded on the Arduino board, thus facilitating its assembly.

The ThingsBoard web platform is dedicated to the Internet of Things, meaning that any device that sends information through the Internet can connect to it; its main objective is to be able to manage and visualize the information they send.

The implementation of free hardware dedicated to the field of geo positioning allows the creation of new services over the network, focused on tracking and allowing its geo reference in real time, as well as the respective sending of information through the mobile network, which allows IoT platforms a real-time reading of the coordinates received and to translate these data into different widgets.

The research carried out was very satisfactory because it led to know several free hardware options that could be used in different ways and with different characteristics, but that would lead to a similar result.

To conclude, the research fulfilled the objectives proposed at the beginning, and the data obtained were well accepted by the herdswomen.

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**Receipt date:** 09/29/2021
**Revision date:** 12/12/2021
**Acceptance date:** 02/27/2022

## Annexes

### Annex 1
***Assembly***

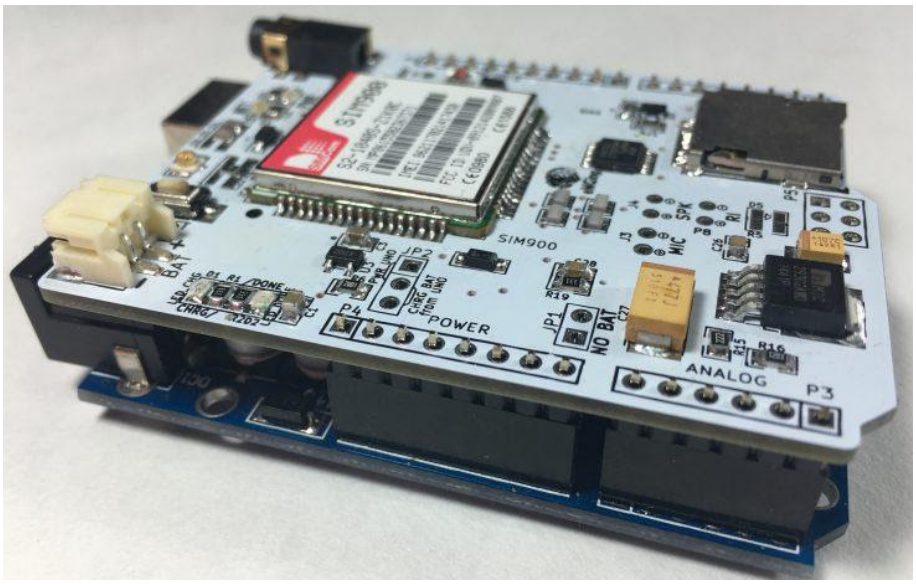


Figure 3. Assembly step 1.
Note: Source: Own elaboration.

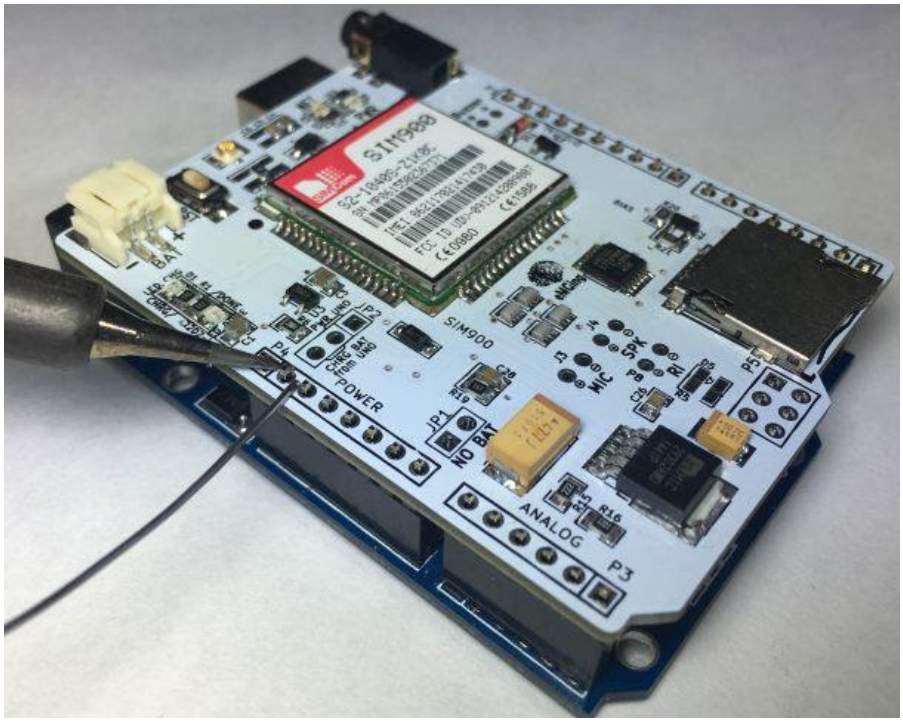


*Figure 4.* Assembly step 2.
*Note:* Source: Own elaboration.


Figure 5. *Assembly step 3.*
*Note:* Source: Own elaboration.

## Annex 2
## *GPS Software Development on Arduino*

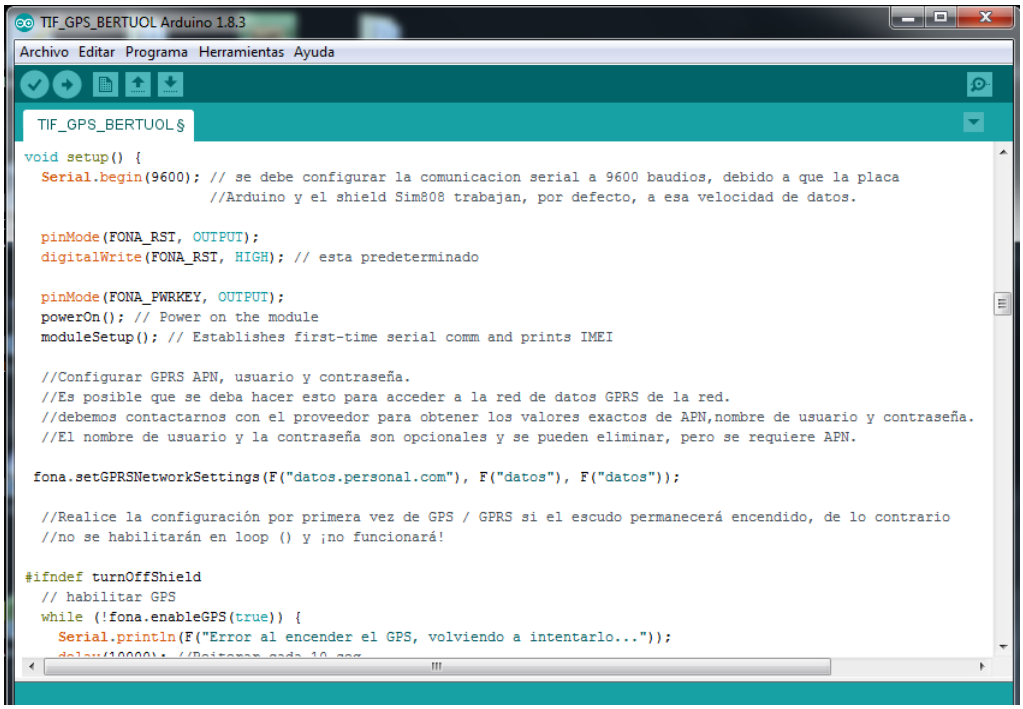


*Figure 6.* Setup subroutine.
*Note:* Source: Own elaboration.

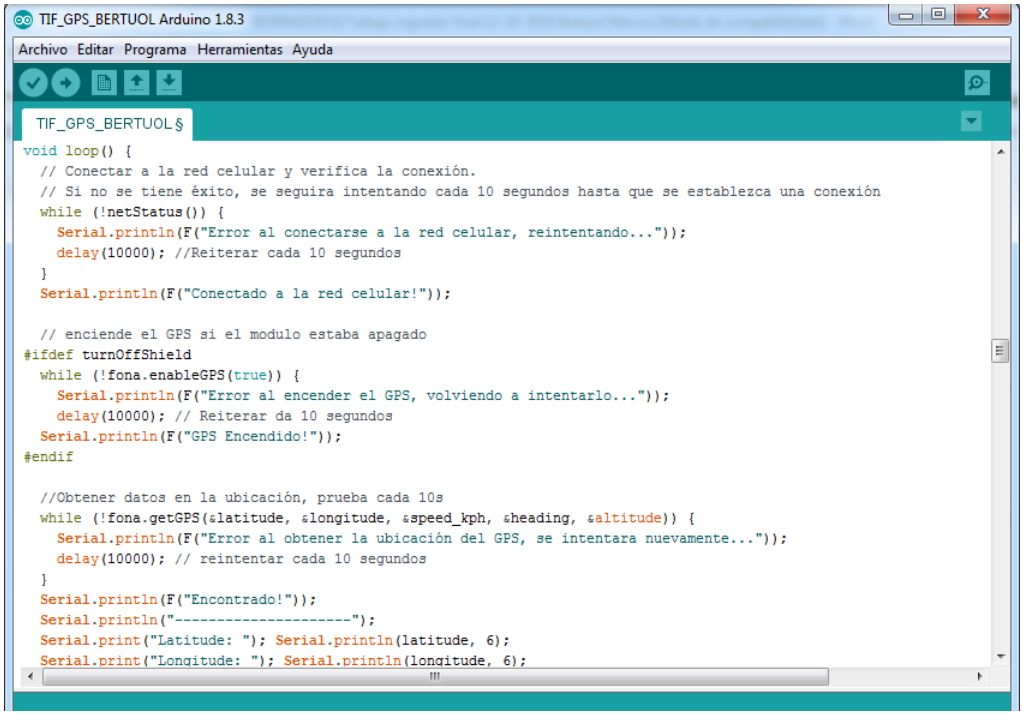


*Figure 7.* Loop subroutine.
*Note:* Source: Own elaboration.

## Annex 3
## *Configuration of the IoT Platform, ThingsBoard*

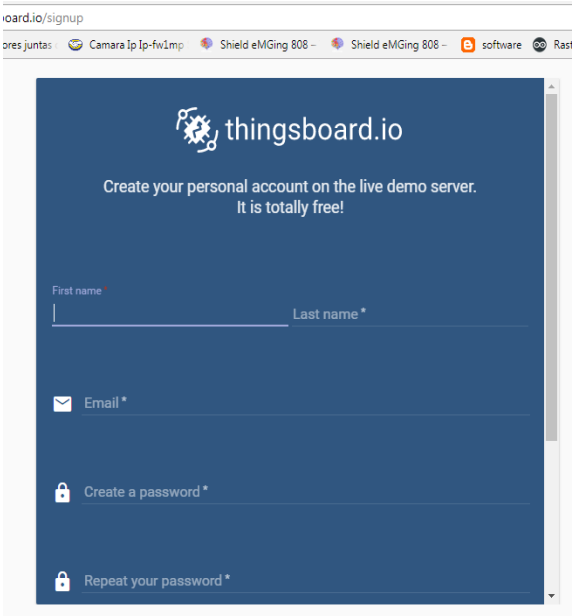


*Figure 7.* IoT platform configuration, step 1.

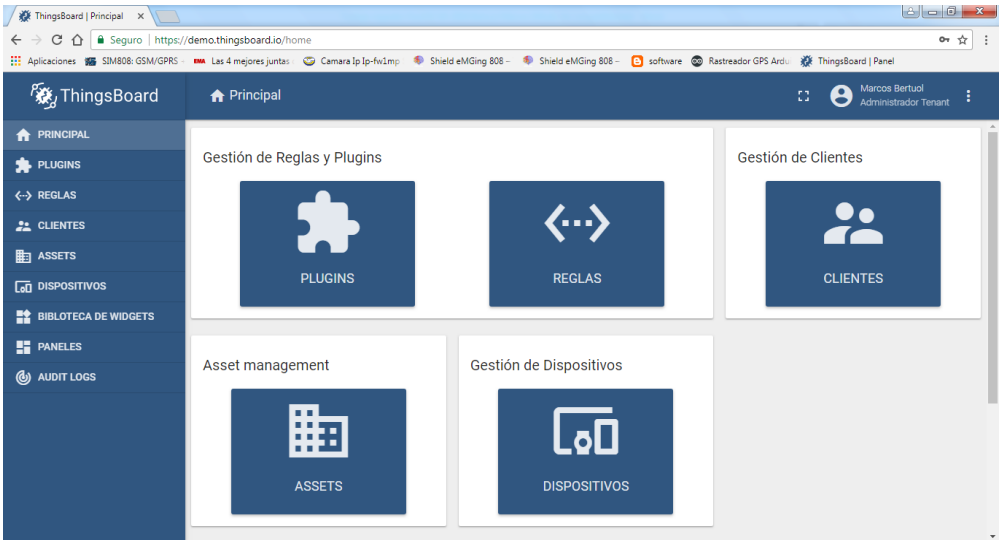


*Figure 8.* IoT platform configuration, step 2.
*Note:* The "Devices" tab on the left side was selected.

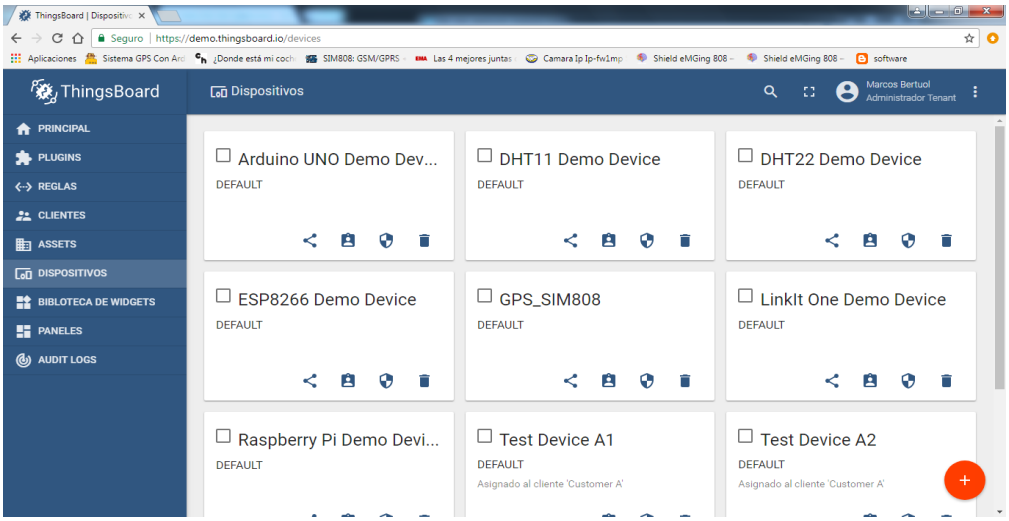


*Figure 9.* IoT platform configuration, step 3.
*Note:* Source: Own elaboration.


*Figure 10.* IoT platform configuration, step 4.
*Note:* Source: Own elaboration.

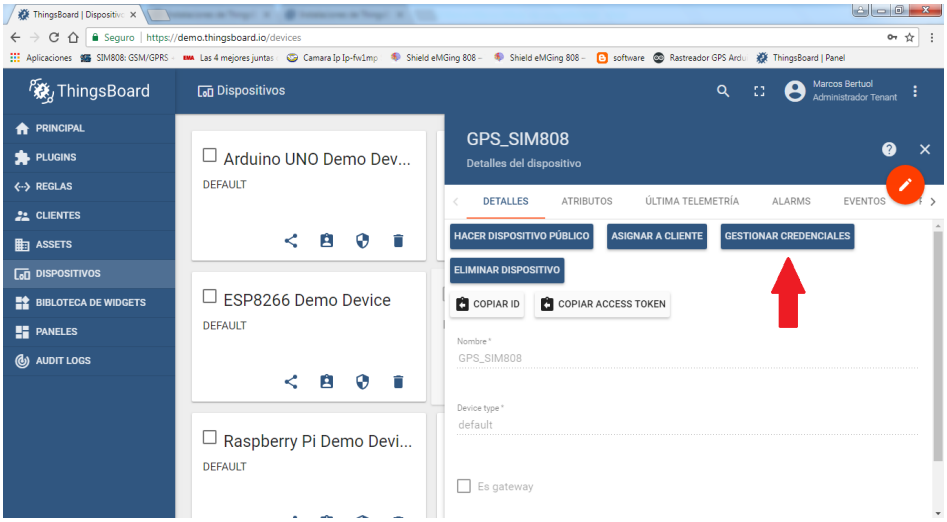


*Figure 11.* IoT platform configuration, step 5.
*Note:* Source: Own elaboration.

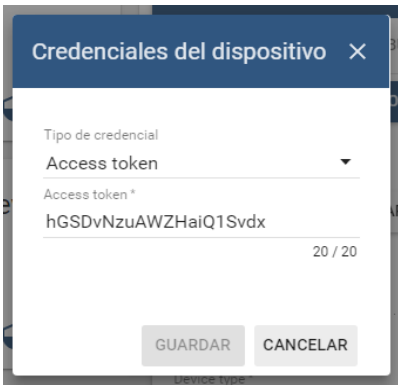


*Figure 12.* IoT platform configuration, step 6.
*Note:* Source: Own elaboration.

## Annex 4
## *Verification of data reception*

It is entered in the same device details page, in the "Last telemetry" tab.

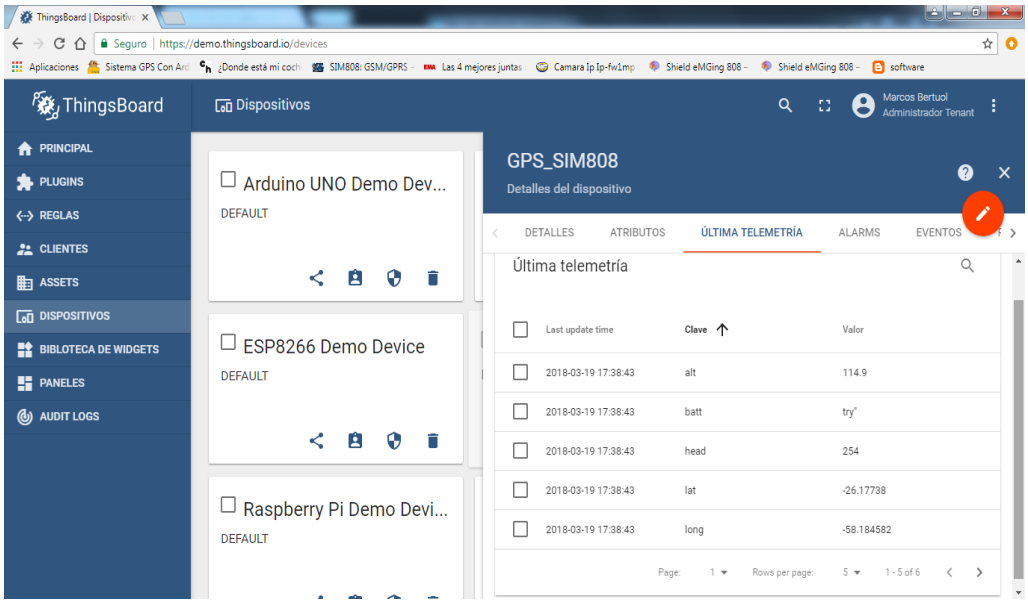


*Figure 13.* Verification of data reception.
*Note:* Source: Own elaboration.

## Annex 5
### *Board configuration*

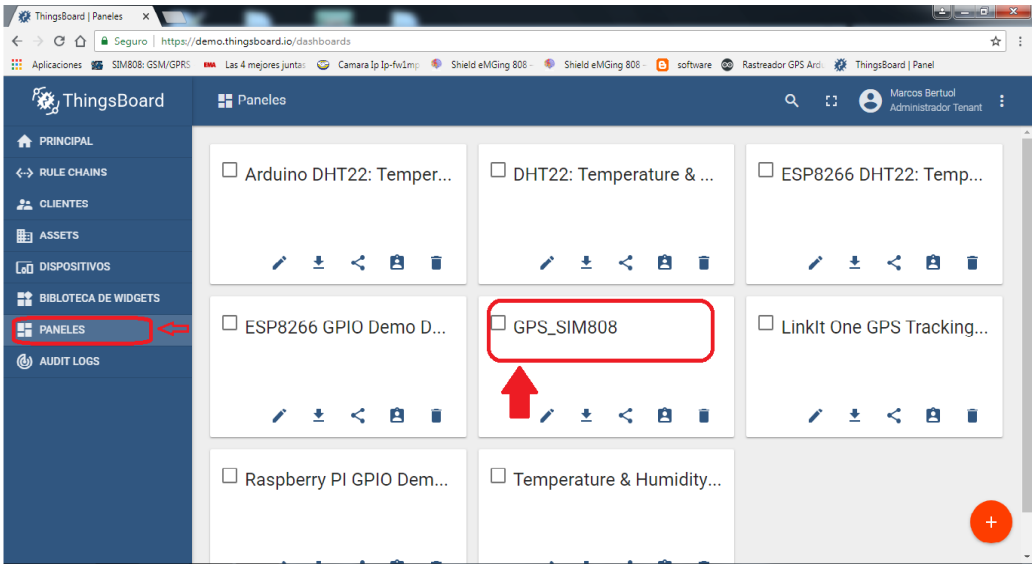


*Figure 14.* Board configuration, step 1.
*Note:* Source: Own elaboration.

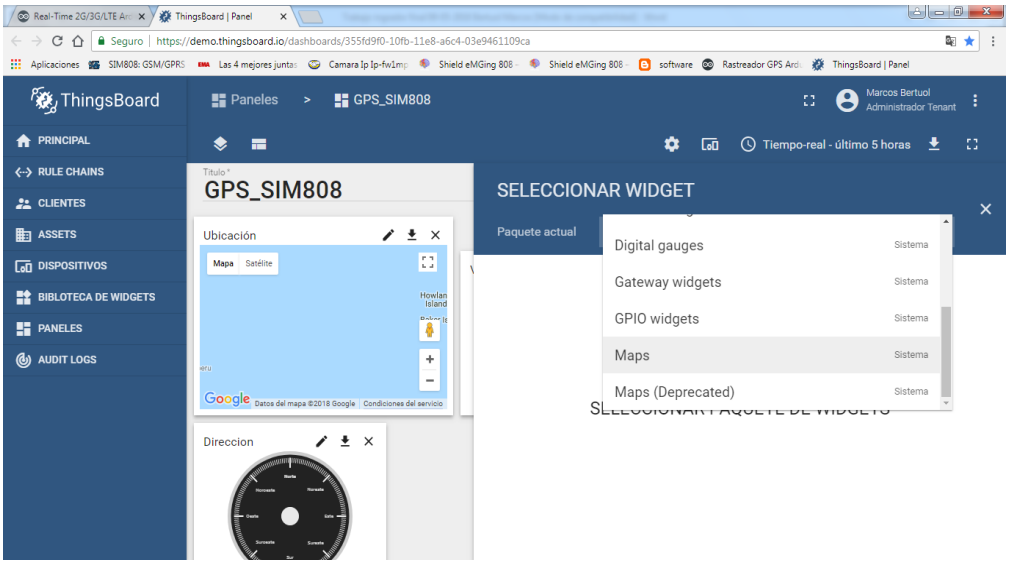


*Figure 15.* Board configuration, step 2.
*Note:* Source: Own elaboration. Selecting this loaded the previews for all the different types of maps that can be chosen.

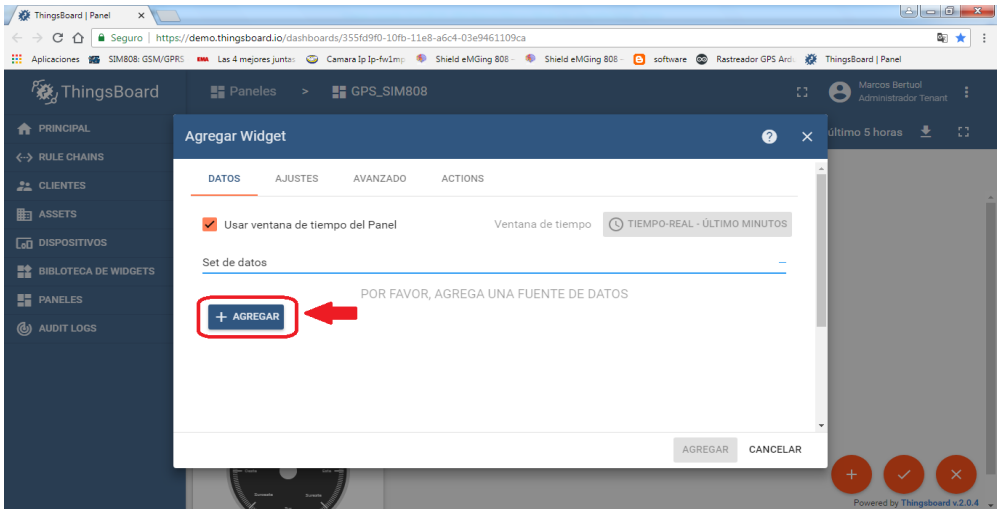


*Figure 16.* Board configuration step 3.

*Note:* Source: Own elaboration. Once the widget has been selected and configured, the prototype can be used.

**PROJECT, DESIGN AND MANAGEMENT**

**ISSN: 2683-1597**

PROJECT DESIGN & MANAGEMENT

**How to cite this article:**

López Rojas, J. B. & Palí Casanova, R. J. (2022). Reciclaje de neumáticos y rentabilidad en empresas de mantenimiento y reparación de vehículos automotores de la región del Maule. *Project, Design and Management,4*(1), 114-127. doi: 10.35992/pdm.4vi1.987

# TIRE RECYCLING AND PROFITABILITY IN AUTOMOTIVE VEHICLE MAINTENANCE AND REPAIR COMPANIES IN THE MAULE REGION

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**Abstract.** This study presents an approach to the growing market of rubber available for recycling, incorporated into the costs of the evaluation of projects related to tire recycling, for which the behavior of companies related to the economic activity of maintenance and repair of motor vehicles in the Maule region in Chile is studied. The topic corresponds to the field of research on environment, quality and prevention and will be framed in the Law of Extended Producer Responsibility and Promotion of Recycling, recently enacted in the country. The methodology used will consider a systemic model composed of inputs, processes and outputs, as well as standards and resources. To establish the inputs, it will be necessary to resort to primary sources of information, which will involve identifying the population of companies that generate tires and determining the sample to be measured through the use of information collection tools and designed so that they can satisfy acceptable scientific criteria, which can be applied by other researchers and their results can be validated, statistically and corroborated by secondary sources. When a real case was used for a given population, a cross-sectional descriptive design was used. The result of the analysis of the information obtained by the SPSS statistical software for quantitative methodologies, determines the discussion and conclusions.

**Keywords:** Recycling, tires, rubber, recovery, Hevea brasiliensis.

# RECICLAJE DE NEUMÁTICOS Y RENTABILIDAD EN EMPRESAS DE MANTENIMIENTO Y REPARACIÓN DE VEHÍCULOS AUTOMOTORES DE LA REGIÓN DEL MAULE

**Resumen.** Este estudio presenta una aproximación al creciente mercado del caucho disponible para reciclaje, incorporado en los costos de la evaluación de proyectos relacionados con el reciclaje de neumáticos, para lo que se estudia el comportamiento de las empresas relacionadas con la actividad económica de mantenimiento y reparación de vehículos automotores de la región del Maule en Chile. El tema corresponde al campo de investigación del medio ambiente, calidad y prevención y estará enmarcado en la Ley de responsabilidad extendida del productor y fomento al reciclaje, de reciente promulgación en el país. La metodología utilizada, considerará un modelo sistémico compuesto por entradas, procesos y salidas, además de normas y recursos. Para establecer las entradas, será necesario recurrir a fuentes primarias de información, lo que implicará identificar la población de empresas que generan neumáticos y determinar la muestra que se medirá a través del empleo de herramientas de recolección de información y se diseñarán para que puedan satisfacer criterios científicos aceptables, que puedan ser aplicadas por otros investigadores y puedan ser validados sus resultados, estadísticamente y corroborados mediante fuentes secundarias. Al usar un caso real para una población determinada, se utilizó un diseño descriptivo transversal. El resultado del análisis de la información obtenida mediante el software estadístico SPSS para metodologías cuantitativas, determinan la discusión y conclusiones.

**Palabras clave:** Reciclaje, neumáticos, caucho, valorización, Hevea brasiliensis.

## Introduction

This study aims to describe the characteristics of the recently created tire recycling market in the Maule region of Chile and to compare the recycling process among the provincial capitals of the region and contribute to solving an alarming environmental problem of concern to the scientific community, by encouraging the disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or being burned inappropriately, posing risks to society, such as fires, infectious outbreaks, and disease transmission.

Studying tire recycling in this region of Chiles is relevant since this information allows us to identify the provinces that need to recycle the largest quantities, the sale prices in the new market, and the risk that may arise when tires are improperly stored.

Chile's macroeconomic indicators present a Gross Domestic Product Per Capita at Purchasing Power Parity (GDP Per Capita PPP, USD-FMI) of US$ 24,744 for 2018 (Central Bank of Chile, 2018), which has produced an increase in the aggregate demand components, impacting the growth of transportation needs and affecting the automotive fleet, which reached 4,680,533 units in 2017 (Cámara de la Industria del Neumático de Chile A.G., 2018). The growth in automotive demand has led to an increase in the number of tires incorporated into new vehicles, and also in the number of tires available as replacements to be used when first-use tires are discarded.

In 2017, 134,860 tons of end-of-life tires were generated in Chile, which is about 10% higher than the 122,757 tons generated in 2016. Regional statistics reveal that the Maule

region contributes 7.9% of end-of-life tires of the country's total (Cámara de la Industria del Neumático de Chile A.G., 2018).

The disposal of tires produces environmental contamination in several ways, such as solid waste as potential shelter for rodents and insects, fire sources that generate air pollution or soil, and groundwater contamination.

This research presents the problem of cost increase in recycling projects, as a result of the creation of a market in the context of the implementation of the Extended Producer Responsibility Law and the promotion of recycling. This type of projects contribute to the decontamination through an industrial recycling system, environmentally friendly, to transform it into a finished product based on rubber, according to world class recycling standards, with quality, innovation, and satisfactory results and with the environmental standards to make it sustainable over time. Likewise, mitigating the environmental impact and the consequences on the health of the population caused by the incineration or inappropriate storage of end-of-life tires, which requires quantifying the available raw material that will allow determining the required plant size for an investment project in a recycling plant for this material.

End-of-life tires are a product with great potential for utilization because they are composed of rubber, metal and textile fiber, which can be separated, transformed, and reincorporated into new production processes through recycling operations (Zarini, 2011). It is important to increase interest in reducing the environmental impact produced by end-of-life tires by reusing them through sustainable methods, which at the same time generate profitability, within the framework of the Law on Extended Producer Responsibility and Promotion of Recycling, which obliges tire producers, whether they are manufacturers or importers, to take care of the waste derived from these products at the end of their useful life.

The study contributes to solving an alarming environmental problem of concern to the scientific community by encouraging the control of the disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or from being burned inappropriately, posing risks to society, such as fires, infectious outbreaks, and disease transmission.

The accumulation of tires should be managed through a productive process from a polluting waste that is not biodegradable to a useful good, taking advantage of the existing technological capacity, with the objective of implementing a recycling plant that is adequate, sustainable, and generates profitability from the financial point of view, adding products with value to society (Olivares, 2016). The problem is aggravated by the incineration of accumulations since this fact produces dangerous atmospheric pollution due to the combustion of toxic components.

Tire recycling in Chile is a recent issue that has become important, mainly because in the last decade the ecosystem in several regions of the country has been affected by this cause due to the fact that private self-regulation has not been sufficient to provide an adequate solution to the acute problem of pollution caused by the collection of end-of-life tires. This has led actors such as the state of the republic and the land transportation industry to seek solutions to the accelerated generation of this negative externality, within a framework of cultural change that in each new generation awakens more and more ecological sensitivity and societies that press for change to be instrumentalized.

The greater ecological awareness of the new generations (Pavez, Leon & Triadú, 2016) responds to a global phenomenon, which has produced effects on legislation in several

countries, including Chile. Since a few years ago, the Chilean state has shown the willingness to implement a law that extends the responsibility to the producer who generates waste, so as to encourage its recycling through a partnership with a third party, with gradual implementation.

On July 01, 2016, the Law of the Republic of Chile number 20,920 on extended producer responsibility and promotion of recycling and its regulations that are established by two Decrees, Decree 7 associated to Article 31 of the Law and Decree 8, associated to Article 4 of the Law, are enacted. Among the wastes considered in this Law of the Republic are end-of-life tires. This law obliges producers, who are manufacturers or importers of priority products, to take care of the waste derived from their products at the end of their useful life.

According to Law 20.920, priority products are lubricating oils, electrical and electronic equipment, batteries, containers and packaging, tires, and batteries.

The criteria for choosing these products are their mass consumption, their significant volume, the generation of hazardous waste, the feasibility of recovery, and the possibility of comparative regulation between them. The end-of-life tire in particular meets all the criteria with the exception of the hazardous waste criterion.

The Law itself defines its objective of reducing the proliferation of this waste and promoting its reuse, recycling, and recovery through the determination of the producer's share of extended responsibility and also determines instruments for the management of this waste in order to protect human health and the environment.

It is the obligation of the entities that generate waste to use an authorized manager for its adequate treatment, unless it decides to manage it by itself, considering that its storage and management must comply with the legal regulations in force at the time (National Congress, 2016).

It is intended to encourage recycling management at the end of the life cycle of products, tending to significantly improve the system of collection, storage, and recovery of materials. Instead of supplying landfills with waste or exporting it to other countries for recycling, it is proposed to take responsibility for the waste generated in Chile, thus make the most of the waste materials produced. Concretely, this law constitutes an economic instrument for waste management that defines the actors who have complementary roles and obligations to achieve such management. (Raglianti, 2018).

The generator of the priority product must register in a public registry, organize, and finance the collection and treatment of priority products, ensuring that the treatment is carried out by authorized managers and must also comply with certain goals and obligations defined by the Ministry of the Environment.

The consumer of the priority product must deliver the end-of-life product to an official waste manager. In the case of an industrial consumer, he may recover his waste himself.

Waste managers, on the other hand, are entities registered with the Ministry of the Environment, whose mission is to declare the type, quantity, costs, origin, treatment, and destination of waste in order to ensure the long-term traceability of waste. Waste managers include collectors and recovery companies.

The Ministry of the Environment has the obligation to establish goals to be followed for priority products, implement and manage the registration system for product traceability, prepare regulations to govern the entire process involved in the Law, and propose environmental education programs to make recycling something intrinsic to consumers.

Other actors are importers and exporters. Extended producer responsibility corresponds to a special waste management regime, under which producers of priority products, such as tires, are responsible for the organization and financing of waste management of the priority products they market in the country (National Congress, 2016).

Decree 7 dated March 17, 2017, associated with Article 31 of Law 20.920, regulates the fund for recycling and states its object that the Ministry of the Environment will have a fund for the prevention of generation, promotion of reuse, and recovery of waste, whose purpose is the total or partial financing of projects, programs, and actions that prevent the generation of waste, promote its separation at source, selective collection, its reuse, recycling, or other type of recovery, executed by municipalities or associations thereof (National Congress, 2017).

Decree 8 dated March 17, 2017, associated with Article 31 of Law 20,920, regulates the procedure for the elaboration of the Supreme Decrees established in said Law (National Congress, 2017).

The Extended Producer Responsibility Act is based on at least the following principles: free competition, transparency, and polluter responsibility, so that "the polluter pays."

They apply to producers, which the Law itself defines as any person who, regardless of the commercial technique used, sells tires as a priority product for the first time on the domestic market or imports it for his own professional use.

In the case of new tires, there are two types of markets globally, the new tire market, which supplies tires for the vehicle industry and for rolling machine manufacturers, and the dedicated replacement market, which allows consumers, carriers, and other companies to have a supply of tires needed to replace those that, due to wear or deterioration, can no longer operate.

Those tires manufactured for original equipment technically do not present significant differences with those manufactured for replacement since both provide the same performance to the vehicles in which they are installed and, therefore, the environmental impact that any of them will have at the end of their useful life will be exactly the same (Cámara de la Industria del Neumático de Chile A.G., 2018).

According to the Chilean Tire Industry Chamber A.G. (2018), in Chile there are practically no vehicle assembly plants, so all original equipment tires enter the market as replaceable components in imported vehicles. For the replacement market, there is only one tire factory in Chile, located in Maipú and owned by "The Goodyear Tire & Rubber Company," a North American company with headquarters in the city of Akron in Ohio, United States. This is a technologically complex plant that produces high-performance tires for passenger cars and light trucks for export markets, of which only a small quantity is sold in the local market. For this reason, just as for the original equipment tire market, it can be considered that the replacement tire market is also composed, almost entirely, of imported tires (Cámara de la Industria del Neumático de Chile A.G., 2018).

According to what was established in the study of technical, economic, and social background for the preparation of the Supreme Decrees that establish the collection and recovery goals for end-of-life tires (Cámara de la Industria del Neumático de Chile A.G., 2018), the tire replacement market in Chile, represents approximately 65% of the total and the remaining 35% corresponds to tires entered as original equipment for vehicles and rolling machinery.

Although Law 20,920 does not consider end-of-life tires to be hazardous waste, they generate significant environmental problems. In general, it is difficult to control fires in places where tires are stored, and tires discarded outdoors accumulate humidity inside them, creating an ideal environment for the reproduction of disease transmission vectors. To minimize these effects, generators must comply with their recycling goals set by the authority, either directly or through managers who collect at collection centers.

The cost of scrap tire handling should be included in the price of replacement tires purchased by a small businessman to continue operating his business; however, it should not be included in the price of a new vehicle purchased by an individual or a large company. Excluding original equipment tires from extended producer responsibility would constitute a discriminatory practice in international trade by subsidizing only vehicle and machinery manufacturers.

It is necessary to consider that tires are manufactured for the sole purpose of being installed on the vehicles or rolling equipment that need them to move, so an out-of-use tire is generated each time a tire is removed from a vehicle and replaced by a new or retreaded tire, provided that the used tire that is discarded is not installed again on the same or another vehicle after being subjected to a repair, redrawn, or retreaded process.

The aforementioned study by the Chilean Tire Industry Chamber A.G. (2018) concludes that the generation of end-of-life tires corresponds to the units of new tires that enter the market to replace them. Tires are replaced because when rolling, the rubber of their upper tread wears out, an element of the tire that is in direct contact with the surface on which it rolls, or because it suffers impacts or damages in its structure that render it useless to continue operating safely. In both cases, the tire reaches the end of its life, or end-of-life tire, and will weigh less than the original new tire, due to the loss of mass due to wear.

The classification of the Chilean Chamber of the Tire Industry A.G. (2018) is presented, which is generally simplified by typifying tires into two types, for light vehicles and for heavy vehicles:

- Car and van: Those used in vehicles for the transportation of passengers or goods.
- Truck and bus: All those used for the collective transportation of passengers or for the transportation of cargo.
- Mining and construction, small and medium: Used in vehicles operating off-highway, in mining or construction sites.
- Mining, large diameter: Used in mining trucks and loading shovels in mining sites.
- Agricultural, forestry, and industrial: Used in industry, ports, agricultural, or forestry tasks.
- Other: Tires for motorcycles, bicycles, wheelchairs, manual carts, and many other applications.

There is an international market called "Tire-Derived Fuel" of sufficient size to export all the end-of-life tires generated in the country that cannot be valorized locally, which limits the cost of collecting end-of-life tires, but although it may seem easier to export end-of-life tires for recycling in countries that have better recycling infrastructure, it is convenient for Chile to be independent in terms of its waste, especially if it wants to make tire generators responsible for the treatment of their waste.

In general, in Chile, end-of-life tires for cars and vans and for trucks and buses are normally recycled, but depending on the region, tires that have been used in mining and agricultural activities need to be incorporated into recycling. Although the costs incurred in

waste treatment may be somewhat higher for tires used in mining activities, transportation costs may be lower when the recovery facilities are located near the mining centers, where the collection of these types of end-of-life tires is concentrated.

After a cutting process to reduce their size, the technologies for the treatment of these tires derived from mining or agriculture need not be significantly different compared to the technologies used in the treatment of tires from other categories. Considering that mining sites have high energy requirements, energy recovery and fuel generation from scrap tires presents opportunities for the development of more sustainable mining.

The collection of large quantities of end-of-life tires at mining facilities, or their transport to generator collection sites, currently presents a complex challenge for mining companies, generators, and managers, in addition to the costs to mining companies of shutting down their sites.

It is advisable to expand the installed capacity in regional collection centers, which requires longer deadlines, investments, and higher technological levels. In this way, it will be possible to know the destination of end-of-life tires, in collection centers of duly authorized managers, in places protected against fires of the accumulated material and that avoid humidity to reduce the risk of proliferation of vectors dangerous to human health indicated in the aforementioned study of the Chilean Tire Industry Chamber A.G. (2018).

The Law on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016) establishes that the generator of end-of-life tires has the obligation to deliver the respective waste to the management system, but the management system will not have the capacity or the legal obligation to remove volumes above its collection goal. If the collection goals are limited, serious conflicts of interest and distortions to free competition may arise when deciding which generators will be favored with the removal of their end-of-life tires and which will have to store them indefinitely in their own facilities.

The case of large diameter end-of-life tires used in mining constitutes an exception since, due to their large volume, it would not be efficient, from an economic point of view, to transfer them to collection centers for subsequent recycling. For this category, the collection targets should be equal to the recovery targets (Cámara de la Industria del Neumático de Chile A.G., 2018).

The collection of already treated end-of-life tires in known locations is important information for investment decisions for end-of-life tire recycling plants, to plan their best location, to stimulate and facilitate the development of the tire recycling industry, and also to reduce the cost per ton transported to recycling plants since whole tires occupy a large part of their volume containing air (Tirel, 2017).

Removing a percentage equivalent to the plant capacity equally for all end-of-life tire generators would impose extremely high collection costs on the management system, consumers, and the transportation industry, without solving the disposal problem for the generator for non-removed end-of-life tires either (Cámara de la Industria del Neumático de Chile A.G., 2018).

On the other hand, withdrawing only from larger generators and those closest to the recycling plants would optimize collection costs during the first years but would be highly unfair to smaller generators, small and medium-sized companies and establishments in the regions, accentuating the excessive centralization of the Chilean national economy.

A business opportunity is envisioned by conceiving a project to install a tire recycling plant in the Maule region, which will process tires that have reached the end of their useful

life to generate crumbs or rubber powder as the main product, which can be used in different product lines detailed in the study.

An end-of-life tire recycling project constitutes a source of sustainable economic development and generates employment, allows replacing imports, freeing productive land, generating environmental awareness, determining the degree of knowledge, and application of the Law of Extended Producer Responsibility and Promotion of Recycling of the Republic of Chile and its regulations (National Congress, 2016 and 2017), provoking concern for generating new laws on the subject and encouraging research work on the properties and uses of recycled material.

It is expected that the study will contribute with an analysis methodology that will allow its transfer to the environment, to evaluate the profitability for investors who have as an alternative projects with the same level of risk, and that can be implemented through innovative applications that are attractive and useful for the market.

## Methodology

A descriptive cross-sectional study was carried out in companies related to "Maintenance and Repair of Motor Vehicles" in the Maule region (Chile). The Maule region is located approximately 250 km. south of Santiago, the capital of Chile. This region has four provinces with capitals called Talca, which is also the regional capital, Curicó, Linares, and Cauquenes.

According to the Chilean Internal Revenue Service, the universe of companies in the Maule region is 273 companies. To select the sample size, the probabilistic (systematic) type was chosen. The following formula was used:

$$n = \frac{Z^2 \cdot N \cdot p \cdot q}{e^2 \cdot (N-1) + Z^2 \cdot p \cdot q} \quad (1)$$

Where: $N$ = 273, size of the universe, corresponds to the companies in the Maule region; $Z$ = 1.96, confidence level corresponding to 95% certainty; $p$ = 0.5, corresponding to the probability of success or expected proportion of companies that generate end-of-life tires; $q$ = 0.5, corresponding to the probability of failure or expected proportion of companies that do not generate end-of-life tires; $e$ = 0.1, precision or maximum admissible error considered to be 10%, using equation (1); $n$ = 71, i.e., the sample size corresponds to 71 companies. To identify the companies, the platform of the Chilean Internal Revenue Service was used for those companies with the line of business of "Maintenance and Repair of Motor Vehicles," which corresponds to the economic activity code "502080."

All companies in the industry and those that agreed to the survey through a representative were included. This procedure was carried out in accordance with the local ethics committee.

A questionnaire of eight questions validated by a panel of experts was used to evaluate the tire recycling variable. The tire recycling variable corresponds to the valued quantity of tires available for recycling, which is composed of the quantity, price, and risk indicators operationalized in Table 1 below.

Table 1
*Operationalization of the tire recycling variable*

| Variable | Indicator | Sub-indicator | Question No. |
|---|---|---|---|
| Tire recycling | Quantity | Generation | P1 |
| | | Quantification | P2 |
| | | Type | P3 |
| | | Action | P4 |
| | Price | Agreement | P5 |
| | | Valorization | P6 |
| | Risk | Type | P7 |
| | | Regulation | P8 |

*Note:* Source: Expert panel. Legend: P1: Tire generation, P2: Monthly tire quantity, P3: Tire type, P4: Tire use, P5: Agreements, P6: Price, P7: Risk due to accumulation, P8: Awareness of the Producer Responsibility Law.

It should be noted that prior to the enactment of Law 20.920 on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016), tires were available free of charge and if removed ended up in landfills.

The instrument was applied by telephone and in person, for which contact was made previously describing the objective of the survey and a second time to carry out the survey. This procedure was carried out by an experienced researcher.

The reliability of the instrument was verified by means of Cronbach's alpha in which a consistency of $r=0.89$ *was* obtained, indicating a high reproducibility of the instrument.

The data were analyzed using descriptive statistics (mean, arithmetic mean, standard deviation, and percentage). A one-way Anova was used to compare between provinces. In all cases, the probability was $p<0.05$. Calculations were performed in Excel spreadsheets and SPSS.

## Results

Table 2 shows the number of tire companies in the Maule region by province. Table 2 shows that the city of Talca has the largest number of companies that recycle tires, followed by Linares, Curicó, and Cauquenes.

Table 2
*Number of companies in the Maule region that recycle tires*

| Number | n | % |
|---|---|---|
| Talca | 32 | 45% |
| Curicó | 11 | 16% |
| Linares | 15 | 21% |
| Cauquenes | 5 | |
| Others | 8 | 11% |
| Total | 71 | 100% |

*Note:* Source: Own elaboration. Legend: Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente, and San Rafael.

Comparisons of the tire recycling process by province are shown in Table 3. It can be seen that the provinces of Talca, Curicó, and Cauquenes reflect significantly higher average values in relation to Linares and other cities in the Maule Region. The cities of Linares and others have shown lower average values than the other cities in the three indicators (quantity, price, and risk).

Table 3
*Comparison of the tire recycling process according to quantity, price, and risk among provinces of the Maule region*

| Indicators questionnaire | Ciudad | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Talca | | Curicó | | Linares | | Cauquenes | | Others | |
| | X | DE | X | DE | X | DE | X | DE | X | DE |
| Quantity | 9,66 | 3,62 | 9,55 | 3,72 | 6,33 | 3,64 | 8,40 | 4,04 | 7,88 | 3,76 |
| Price | 6,41 | 2,66 | 6,45 | 3,11 | 3,73 | 2,99 | 5,20 | 3,35 | 4,50 | 3,07 |
| Risk | 4,63 | 1,58 | 4,27 | 1,49 | 3,53 | ,99 | 4,20 | 1,10 | 3,75 | ,89 |
| Total | 20,69 | 7,01 | 20,27 | 7,81 | 13,60 | 7,43 | 17,80 | 8,17 | 16,13 | 7,20 |

*Note:* Source: Own elaboration. Legend: X: Average, SD: standard deviation Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente and San Rafael.

There were no differences between Talca and Curicó ($p>0.05$); however, between these two cities (Talca and Curicó), there were significant differences when compared with the other cities (Linares, Cauquenes and others). In addition, no differences were found between the cities of Linares, Cauquenes, and others ($p>0.05$). These results, shown in Figure 1, indicate that the cities of Talca and Curicó recycle more tires than the other cities.

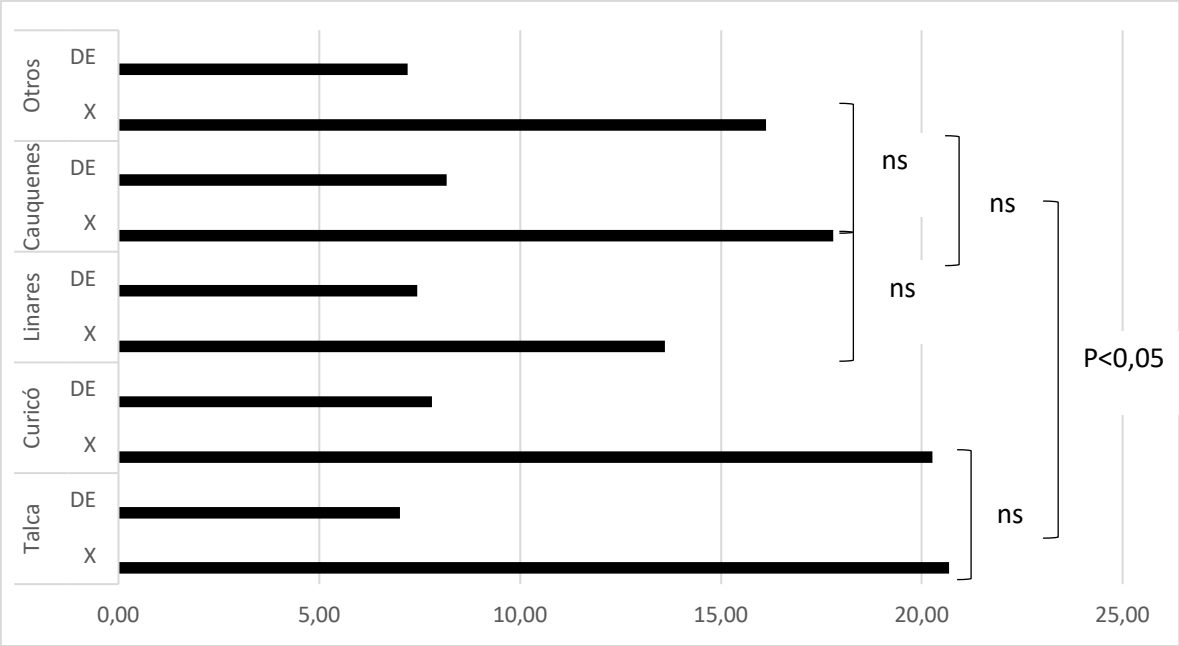


*Table 1.* Descriptive values of the tire recycling process obtained from the tire recycling questionnaire in the Maule region.

*Note:* Source: Own elaboration. Legend**:** P: total score of the questionnaire, ns: mean score, X: average, SD: standard deviation, Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente, and San Rafael.

## Discussion

The results have shown that of the four cities, Talca, Linares, and Curicó, have the highest number of companies that recycle tires, followed by Cauquenes and others.

When compared by quantity, price, and risk, the cities of Talca and Curicó presented higher values in relation to the other cities. This is due to the fact that these cities had 32 and 11 companies, presenting consequently higher quantity, price, and risk, respectively. In addition, these cities have greater vehicular flow, population density, and development of services.

The city of Linares, despite having 15 companies, has shown low average values in relation to the other cities, which could be due to the fact that these companies are redistributors of companies from Talca, the capital of the region, but do not have an agroindustrial development comparable to Curicó, which is located to the north of the region and closer to the capital of the country.

Regional statistics reveal that the Maule region contributes 7.9% of end-of-life tires of the country's total (Cámara de la Industria del Neumático de Chile A.G., 2018).

Peláez, Velásquez, and Giraldo (2017) argue that the remains of disused rubber have become an environmental and public health problem. Governments have enacted legislation with the objective of mitigating the negative impact caused by end-of-life tires, which, in the case of Chile, considers tire generators responsible for exercising a recycling quota, thus accelerating the search for alternatives for the use of the end-of-life tire and modifying the

profitability of the recycling plants of this raw material that acquires greater economic value for this market.

This research aims to contribute to the study of costs leading to the solution of a serious environmental problem of concern to the scientific community, which is to encourage the control and disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or being burned inappropriately, posing risks to society of fires, infectious outbreaks, and disease transmission.

Under the right conditions, the reuse of rubber obtained from recycled end-of-life tires is not harmful to either human health or the environment, functional characteristics that are desirable to encourage its use (Peláez et al., 2017).

The increase in the cost per raw material becomes relevant with the implementation of Law 20.920 on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016) since, prior to its enactment tires, were available for free as generators had the options of keeping the waste in storage or paying for its removal to municipal dumps.

It is the obligation of the entities that generate waste to use an authorized manager for its adequate treatment, unless it decides to manage it by itself, considering that its storage and management must comply with the legal regulations in force at the time (National Congress, 2016).

The regulation of Law 20.920 establishes mandatory recycling quotas corresponding to 30%, 2021 will reach 50%, and 2028 should reach 90%, which forms a regulatory framework for a market that opens business opportunities, varying prices and available quantities of its raw material recycling (National Congress, 2017).

The average variable cost, identified by Sapag et al. (2014), represents the marginal cost of producing one more unit, which, in terms of raw material, corresponds to the acquisition price of each unit which in our sample is US$1.7, the quantity of the population corresponds to 7,402 units, so the total variable cost is US$12,853.

## Conclusions

This study shows that the recycling process in the Maule region (Chile) is a function of the number of companies in the city, so that the cities of Talca and Curicó, which have a greater number of companies, consequently have high recycling values in relation to the other cities. However, the city of Linares, which has a large number of companies, had low recycling values, which apparently may have low levels of recycling and could present a greater risk of contamination in the region; however, it was verified by telephone corroboration that they are distributors of companies in the city of Talca or Santiago, the capital of the country.

The increase in the cost of raw materials affects recycling costs and is, therefore, a relevant factor to consider when calculating the profitability of recyclers with respect to the previous situation of eventual free recycling (Pérez and Pérez, 2006).

The sales price in a scrap tire recycling project must absorb the cost of raw material, which is a fundamental part of the cash flow that must be projected to determine the profitability of the investment (Tirel, 2007) of installing a scrap tire recycling plant in the Maule region of Chile.

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**Receipt date:** 12/19/2021
**Revision date:** 01/07/2022
**Acceptance date:** 04/21/2022

PROJECT, DESIGN AND MANAGEMENT

ISSN: 2683-1597

**How to cite this article:**

Silva Cascante, Á. V., Calvo Barriga, M. I., Vázquez Mora, C. A. & Uría, G. R. (2022). Hacia el rescate de una cultura constructiva de morteros con materiales y técnicas constructivas tradicionales para una correcta intervención patrimonial. *Project, Design and Management,4* (1), 128-153. doi: 10.35992/pdm.4vi1.905.

# TOWARDS THE RESCUE OF A CONSTRUCTIVE CULTURE OF MORTARS WITH TRADITIONAL CONSTRUCTION MATERIALS AND TECHNIQUES FOR A CORRECT PATRIMONIAL INTERVENTION

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**Abstract.** This research seeks to establish the proper use of traditional materials such as: lime, mud, mountain, straw and nopal mucilage; to be applied in restoration from the investigation of the mechanical behavior of the new dosages. The traditional materials used in testing new mortar designs, are from the San Diego convent in the city of Quito. Three new mortar dosages were designed with different percentages in each of its elements. The purpose of the investigation is to obtain different parameters to make a comparison between each of the mechanical tests such as: compression, bending, and traction to which the new models were subjected. The traditional materials used are of similar characteristics to those found in the investigation of ancient mortars. In the experimental study, the new specimens were subjected to mechanical tests in which the characteristics and resistance to compression, tension, and bending were obtained and determined. These new dosages were experienced at different ages such as: 14, 21, and 56 days. All new specimens were kept in the same temperature and humidity conditions existing in the laboratory. Under these parameters, the dosage that met the best characteristics for an architectural restoration process was established.

**Keywords:** traditional materials, dosages, mortars, tests and restoration.

# HACIA EL RESCATE DE UNA CULTURA CONSTRUCTIVA DE MORTEROS CON MATERIALES Y TÉCNICAS CONSTRUCTIVAS TRADICIONALES PARA UNA CORRECTA INTERVENCIÓN PATRIMONIAL

**Resumen.** Esta investigación busca establecer el buen uso de los materiales tradicionales como: cal, barro, paja de monte y mucilago[1] de nopal; para ser aplicados en la restauración a partir de la investigación del comportamiento mecánico de las nuevas dosificaciones. Los materiales tradicionales utilizados en el ensayo de los nuevos diseños de morteros, son los que se obtuvieron como resultado de la investigación realizada a los morteros originales del convento de San Diego de la ciudad de Quito. Se diseñaron tres nuevas dosificaciones de morteros con diferentes porcentajes en cada uno de sus elementos. El propósito de la investigación es obtener diferentes parámetros para realizar una comparación entre cada uno de los ensayos mecánicos como: compresión, flexión y tracción a los que fueron sometidos los nuevos modelos. Los materiales tradicionales utilizados son de similares características que los encontrados en la investigación de los morteros antiguos. En el estudio experimental las nuevas probetas se sometieron a pruebas mecánicas con las que se obtuvieron y determinaron las características y resistencia a la compresión, tensión y flexión. Estas nuevas dosificaciones se experimentaron a distintas edades como: 14, 21 y 56 días. Todas las nuevas probetas se conservaron en iguales condiciones de temperatura y humedad existentes en el laboratorio. Bajo estos parámetros se llegó a establecer la dosificación que cumplió las mejores características para ser utilizada en un proceso de restauración arquitectónica.

**Palabras claves**: materiales tradicionales, dosificaciones, morteros, ensayos y restauración.

## Introduction

The study shows the complexity and interest in determining the characterization of old mortars of monumental buildings belonging to the Historical Heritage. Our interest is to establish the feasibility of safeguarding and correct restoration of the heritage with the use of new mortars appropriate for rehabilitation. These should be as similar as possible to the original ones both in materials and in traditional construction techniques to maintain the values of the heritage work.

Mortars prepared with traditional materials and techniques have been used throughout time as construction elements, both for private buildings and for monumental works. Within the city of Quito, Ecuador, there is an important Historic Center where colonial architecture built with traditional materials can be found. One of the important buildings that maintains much of its original construction is the convent of San Diego, where we find walls of mud, adobe, brick, stone, suro, chaguarquero, and wood, in general (Universidad de Las Américas, 2016).

The Municipality of the Metropolitan District of Quito is the entity in charge of applying a management policy focused on revitalizing historic areas recognized as essential elements of the local identity and maintaining the value of the historic ensemble of heritage elements, in order to guarantee their permanence in time through monumental restoration. Unfortunately, in certain restoration projects, there is evidence of a lack of adequate studies, coupled with the lack of specialization and professional knowledge of certain executors, the lack of research in the area of architectural restoration, and the

[1] Organic substance of viscous texture, similar to gum, obtained from nopal cactus by means of the aqueous extraction system

absence of proper monitoring of management policies applied to the intervention of heritage buildings has led to the fact that some projects, after a short time of having been recovered, have to be intervened again.

The appearance of Portland cement has caused the use of traditional materials for joints, masonry, and plastering to be reduced, causing their near disappearance in the use for construction in general and in the field of restoration, causing a loss in the historical authenticity of heritage buildings (Usedo, 2015).

This research aims to contribute with knowledge on the use of traditional materials for a correct restoration and recovery of heritage buildings. For this purpose, it was necessary to analyze the old mortars of a colonial building. In this case, the selected building was the convent of San Diego in the city of Quito.

*Figure 1.* Main façade of the "San Diego" convent. Quito, Ecuador
*Note:* Source*:* Own elaboration, 2021

### *Research design*

This research has an experimental methodology to establish the behavior that is presented during the intentional manipulation of the materials (lime, mud, straw, nopal mucilage), which are used in the elaboration of the new mortars. The mechanical measurement of tension, compression and bending, to which all the specimens of the new mortars were subjected, was carried out. The values obtained allowed a quantitative measurement reading to be made, which is used to compare the proposed mortar models. With these results, we will proceed to evaluate which one or ones have the best physical and mechanical properties to be used in an architectural restoration process.

The ASTM C305 method is used to obtain the values to determine the mechanical qualities of the new mortars tested (Hernández, Collado, and Baptista, 2014).

### *Analysis of original mortars*

For the present study, eight (8) samples were taken, each of them from different construction stages (four periods[2]) of the *San Diego convent.* The samples were taken from a historic monument, so we respect the criterion that this heritage property cannot

[2] Periods of construction of the San Diego convent

be altered. The ecclesiastical authorities decided the site and the amount of sample that could be taken (Kennedy Troya & Ortiz Crespo, 2010).

The analysis of the ancient mortars was performed in the chemistry laboratory of the National Institute of Cultural Heritage (INPC[3] ), the investigation of the specimens for research was based on standards and methods such as, for example: ASTM C267 - 01(2012), PEE-LABINPC-04, Hernández, Pfeiffer Perea, & Cano Barrita, (10 of 1 of 1 of 2018). This study allowed to know the characteristics, properties and variants of the mixtures, all the mortars were subjected to several evaluations such as: the observation

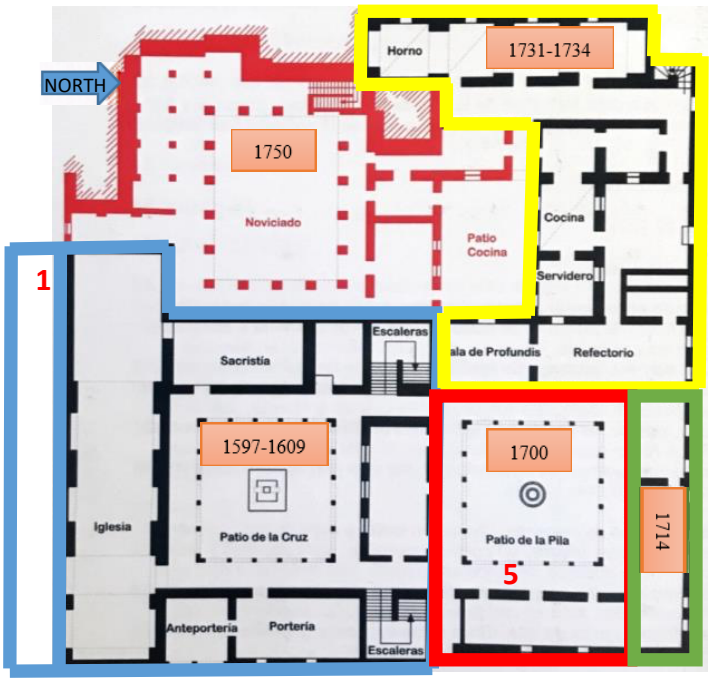


*Figure 2***.** Delimitation of the construction periods of the San Diego Convent with the sampling points.
*Note.* Source*:* Own elaboration, 2019

petrographic analysis, volumetric and granulometric analysis, elemental chemical analysis, and the presence or absence of organic additives in the mortars were also analyzed. This information allowed us to know the structure of the original mortar, composed of lime, mud, bush straw, and cactus mucilage (Silva Cascante et al. 2020).

Based on the analysis of the old mortars and using the results of the general composition of the samples analyzed, research was started on the new mortars prepared with traditional materials. These studies expose the composition percentages of each original mixture, being the basis for preparing three (3) new dosages. This will establish the most appropriate combination to be used in architectural restoration processes.

The reference values are obtained by scanning electron microscopy analysis (SEM-EDS) on the originals. This procedure consists of obtaining the chemical and microscopic composition of each of the materials, determining the chemical structure of the fragments analyzed, and establishing the morphological characteristics and

[3] National Institute of Cultural Heritage (INPC)

combinations. These data will serve as the basis for new dosages to be applied in another mortar (INPC, 2019).

Table 1
*General composition of old mortars*

| SAMPLE | % Lime as (CaCO3) | % Mud | % Vegetable fibers | % Mucilage [4] |
|---|---|---|---|---|
| 19-07-05 | 8,06 | 76,28 | 1,23 | 9,42 |
| 19-07-6 | 18,19 | 74,79 | 1,03 | 5,99 |
| 19-07-7 | 3,64 | 92,97 | 1,74 | 1,88 |
| 19-07-8 | 10,90 | 85,73 | 1,74 | 1,63 |
| 19-07-9 | 3,52 | 87,88 | 1,11 | 1,49 |
| 19-07-10 | 11,35 | 85,72 | 0,99 | 1,93 |
| 19-07-12 | 3,79 | 95,61 | - | - |
| 19-07-13 | 4,58 | 93,48 | 1,62 | - |

*Note:* Source*:* INPC Chemistry Laboratory, 2020

***Dosage approach for the production of new mortars***

The samples obtained of original mortars from the different stages of construction of the San Diego convent are made of lime, mud, straw, and cactus mucilage. The goodness, characteristics, and proportions of these traditional mortars were also established. The research made it possible to recover part of the ancestral knowledge about the value and quality of the traditional materials.

To make the new formulations, the highest values of the original mortars analyzed were considered; in this way, the mathematical average was used to establish the new dosages with which the laboratory experimentation of the new mortars was carried out.

Table 2
*Dosages for the experimentation of the new mortars*

| Mortar type | Cal | Mud | Nopal slime | Bush straw % of |
|---|---|---|---|---|
| Type 1 mortar | 2 | 6 | 1 | 1% |
| Type 2 mortar | 1.5 | 6.5 | 1.5 | 1% |
| Type 3 mortar | 1 | 7 | 2 | 1% |

*Note:* Source*:* Own elaboration, 2021

[4] Organic substance of viscous texture, similar to gum, obtained from the nopal plant by the aqueous method.

The experimental test was carried out in the soil laboratory of the Universidad Católica de Quito (PUCE), which conducted the study under the American standards ASTM C305: *Standard Test Practice for Mechanical Mixing of Hydraulic Cement of Hydraulic Cement pastes of Plastic Consistency,* from which the mortars' interpretation values were obtained.

For the new models, the volumes of each material were formulated and their proportions are a function of volume and weight of the different ingredients used. For their interpretation: lime (binder); mud/nopal mucilage (vegetable additive); mountain straw (% of volume of the mixture). For purposes the proportion was: (1:5:2:2%).

For this test of the new dosages to be analyzed, 27 specimens were taken for each new sample, i.e., a total of 81 models were made with which the mechanical tests were performed, which were tested at "14, 21, and 56" days of age with each prototype.

The mechanical tests carried out were as follows:

Compression. - fm=P/A

Tension/Traction. - RT=50*Max Load/Cross-sectional Area

Bending. - K ring=3.43 kg/1/10000

### *Material selection*

The mortars used in restoration are characterized by their nature, their history, their structural behavior, low cost, easy to replace, and compatible with the environment as well as their constituent parts are the aggregates, binders, and additives; according to the analysis obtained from the investigation of the old mortars, traditional materials, such as lime, mud/clay, moor straw, and cactus slime were selected.

However, it is worth mentioning that in the country (Ecuador) there is no quality control on the stone materials that are used in construction, despite the existence of the Ecuadorian Construction Standard (NEC) (NEC-SE-MP), which is in force since January 10, 2015, and its compliance is mandatory; thus, the control on traditional materials is null and in this case we proceed to look for local materials that maintain similarities with the original materials that are part of the building to be intervened.

***Cal***

Historically, lime is the most used product and currently of necessary use and interest in conservation, considering that this material is not very industrialized and commercialized in our environment. In addition, there is no certified brand of production that complies with national standards; in spite of this, it is possible to obtain it in certain points of sale, it can be acquired as quicklime (in stone) to undergo the slaking process. For this research, slaked lime was used (Pinganrrón and Villaseñor, 2013).

However, it is essential to determine the good quality of the limestone, which must have a high calcium carbonate content and be adequately hydrated to obtain the lime paste, for which different requirements must be met:

To make a careful selection of the limestone, which must have enough purity.

1. One of the indispensable requirements is that the limestone must have a high degree of burned out (900 °C).
2. Another factor that must be taken into account is the slaking process of limestone. This depends on the amount of water and the time it is kept submerged, i.e., if the

slaking time is longer, the paste will be of higher purity and better quality (Villalobos Ruiz, 2014).

*Figure 3.* View of slaked lime
*Note:* Source*:* Own elaboration, 2019

In the experimentation, slaked lime was used since the research of old mortars determined its presence in the analyzed mixtures. For its application, the study of quicklime and its similar in water (slaked lime) was carried out to reach the results these were subjected to FTIR-ATR analysis.

***Mud / earth***

Mud or clay is the finest disintegrable material of the earth that forms part of the natural soil. According to its formation, the mineral that predominates in a clay will determine its volume, which is established by its location and collection site. In addition, it should be considered whether these are of inorganic character, i.e., they are the product of the decomposition of rocks or organic originate from the decomposition of living organisms. These are the factors that determine the characteristics of existing clays and establish their different uses (La Spina, 2014).

For this experimentation, ancestral knowledge on the use and management of traditional materials was used. First of all, a visual verification of the sector where excavation was carried out to collect the soil was made, it was evidenced that it was free of organic impurities, a factor that helped to determine that the clay of this site is suitable or not to be used in the elaboration of the mixtures. The most adequate soil (mud/earth) was extracted prior to the excavation at an adequate depth. The soil with the best characteristics for construction use is generally collected at a depth of 50 centimeters from ground level, as it is the most appropriate and has a varied granulometric composition, which allows the soil to remain more stable by modifying its moisture conditions (Gatti, 2012).

*Figure 5. Selected* mud view
*Note:* Source*:* Own elaboration, 2019

## ***Nopal mucilage***

The nopal (Opuntia ficus-indica) is a cactus from which an organic substance known as mucilage is obtained in the field of construction in general and specifically in the restoration plays the role of adhesive. This material is a biopolymer that waterproofs and binds materials in this case to traditional materials, such as earth and lime. This nopal gum improves the mechanical characteristics in mortars. The selected nopal cactus should be 2 to 3 years old. The stalks should be approximately 25 to 30 cm long and should be cut at the bottom of the stems.

To use the cactus stalks, the thorns are cleaned and then washed in drinking water in order to prevent them from becoming embedded in the skin, facilitating its handling, then cut into small square pieces about 2 cm, a step that facilitates the extraction of mucilage.

There are several methods for the extraction of cactus mucilage and its application in traditional construction, especially in restoration (Martínez et al., 2008).

Some ways to perform the extraction are:

1. Cold (room temperature) aqueous extraction process.
2. Cooking extraction process (at an average temperature of 90º C).
3. Drying process (dehydration of the cactus paddle), then the paddle is subjected to a grinding process, and finally the cactus powder is obtained to be used in the blends.

For this experiment, the mucilage was extracted using the cooking method to obtain the greatest amount of the product. This method was preferred because in the study carried out on traditional mortars, it was determined that the cooking method was used. The comparison standards used to determine the presence of an organic vegetable additive were mucilage obtained at cold (room temperature) and cooking (90º C) **(Silva Cascante et al., 2020)**.

The mucilage obtained by firing has a thicker, adhesive, and light green structure, according to the spectrum found in the analysis of ancient mortars.

*Figure 7.* View of the nopal obtained by cooking (mucilage*).*
*Note:* Source*:* Own elaboration, 2019

### *Paramo straw*

For the study of the new mortars, paramo straw of native origin (Calamagrostis effusa), a plant from which a natural fiber is obtained, is a plant characteristic of semi-arid areas and is found at an altitude of more than 3,000 m. and grows naturally. It has a composition of lignocellulose (combination of lignin and cellulose), the amount of straw provided by the plant is given by its variety and age. This fiber is biodegradable and low cost.

In addition, there are several types of straw as an agricultural by-product, dried stalks of cereals, such as wheat, barley, rye, and other species that are used in the field of traditional construction.

In the analysis of ancient mortars, this element of organic origin was found, which improves the mechanical characteristics of the final product. For its use, it is recommended that the straw be in a dry state, that the plant should be cut at full moon, and dried in the open air by means of the sun's rays to avoid rotting; this natural fiber in the mortars in the drying process prevents the plaster from cracking without altering the characteristics of the traditional materials, preventing the erosion of the plaster.

In the experimentation of the new mixtures, straw was used in a dry state and with an average length of 2 to 4 cm in length (Sánchez, 2012).

*Figure 8.* View of the weighing of the paramo straw
*Note:* Source*:* Own elaboration, 2019

### *Experimentation*

For this research, data obtained from the study of the original mortars of the building of the San Diego convent were used to determine the components and composition percentages of the analyzed mixtures. On this basis, it is intended to demonstrate that coatings made with traditional materials, such as lime, mud, mountain straw, and cactus mucilage can be a solution for an appropriate restoration. These dosages should have similar characteristics to the traditional mixtures, with properties, such as durability, permeability, and compatibility with the materials that make up the building.

The objective of carrying out this test through a laboratory is to measure, by means of the tests, the capacity to withstand the different mechanical stresses to which the specimens are subjected. To achieve this objective, three new formulations were designed, different from each other, but with the same type of material: lime, mud, and cactus mucilage. They are interpreted in volume and the straw is a percentage (1%) in relation to the sum of the total volume of the three previous ones. The standard dosages are shown in tables 3, 4 and 5.
Interpretation of the dosage:
(Mud: lime: mucilage: straw in % of the volume of the mixture).

Table 3

*Dosage of the new formulation mortar No. 1*

| **DOSAGE NO. 1** | | |
|---|---|---|
| Measurement / Weight = 167.92 gr. | | |
| Material | Proportions | Weight (gr) |
| Mud (B) | 7 | 1175.44 |
| Lime (C) | 1 | 244.00 |
| Nopal Mucilage | 2 | 309.88 |
| Straw (P) | 1% of total weight of B+C+N | 17.29 |

*Note:* Source*:* Own elaboration, 2019

Table 4

*Dosage of the new formulation mortar No. 2*

| **DOSAGE NO. 2** | | |
|---|---|---|
| Measurement / Weight = 167.92 gr. | | |
| Material | Proportions | Weight (gr) |
| Mud (B) | 6.5 | 1091.48 |
| Lime (C) | 1.5 | 366.00 |
| Nopal Mucilage | 2 | 229.80 |
| Straw (P) | 1% of total weight of B+C+N | 17.29 |

*Note:* Source*:* Own elaboration, 2019

Table 5

*Dosage of the new formulation mortar No. 3*

| **DOSAGE NO. 3** | | |
|---|---|---|
| Measurement / Weight = 167.92 gr. | | |
| Material | Proportions | Weight (gr) |
| Mud (B) | 6 | 1007.52 |
| Lime (C) | 2 | 488.00 |
| Nopal Slime | 1 | 154.94 |
| Straw (P) | 1% of total weight of B+C+N | 17.29 |

*Note:* Source*:* Own elaboration, 2019

The experimentation of the models of the present study is based on the breakage of the samples in different tests where the mechanical resistance to compression, tension, and bending is measured. For each of the tests, 27 samples were taken for each formulation. The experimentation of each sample was tested at "14, 21, and 56 days" of age of each model.

*Figure 9.* View of *test* specimens
*Note:* Source*:* Own elaboration, 2019

To weigh the materials, a container was used as a unit of volume, with a capacity of 170 g (1 unit), which was used to weigh the new formulations.

In the elaboration of the models for the different mechanical tests, different molds were used. Their shapes vary depending on the type of mechanical test to be performed; thus, we can indicate:

- Mold for *compression* test, cube-shaped, 5.0 x 5.0 x 5.0 cm.

*Figure 10*. Mold for compression test
*Note:* Source*:* Own elaboration, 2019

- Model for *bending* test. It has a rectangular bar shape of 16.0 x 4.0 x 4.0 cm.

*Figure 11*. Mold for flexural test
*Note:* Source*:* Own elaboration, 2019

- Matrix for the *traction* experiment. It has the shape of a bow tie and its dimensions are 7.5 x 2.5 x 4.0 cm.

*Figure 12.* Mold for tensile test
*Note:* Source*:* Own elaboration, 2019

The mixtures were carried out mechanically. A three-speed industrial *mixer* (*mortar mixer*) was used, with a paddle for mixing. In this research, the mixing of the different materials was done at a low speed, and fixed mixing times were used for each material added. The times used per sample were:

- Mud + straw for 30 seconds.
- Addition of lime for 30 seconds.
- Addition of nopal mucilage for 60 seconds.

In order to make the mixture more homogeneous, the mortar was subjected to an additional 30 seconds of high-speed mixing.

*Figure 13*. Industrial mixer
*Note:* Source*:* Own elaboration, 2019

With the final mixture, we proceed to fill each of the prototypes. This is done manually; the mixture is poured into each of the molds in two stages. Between each of the periods, each layer will receive 15 strokes so that the mixture fills all the voids and the air leaves the mold. Once the filling of the prototypes is completed, they are subjected to a drying process inside the mold at room temperature for a period of 7 days. After this period, the matrices were disassembled and the specimens were removed, which were then subjected to a curing process. When the models reached the programmed age cycles for the tests (14, 21, 56 days), they were subjected to the different mechanical tests.

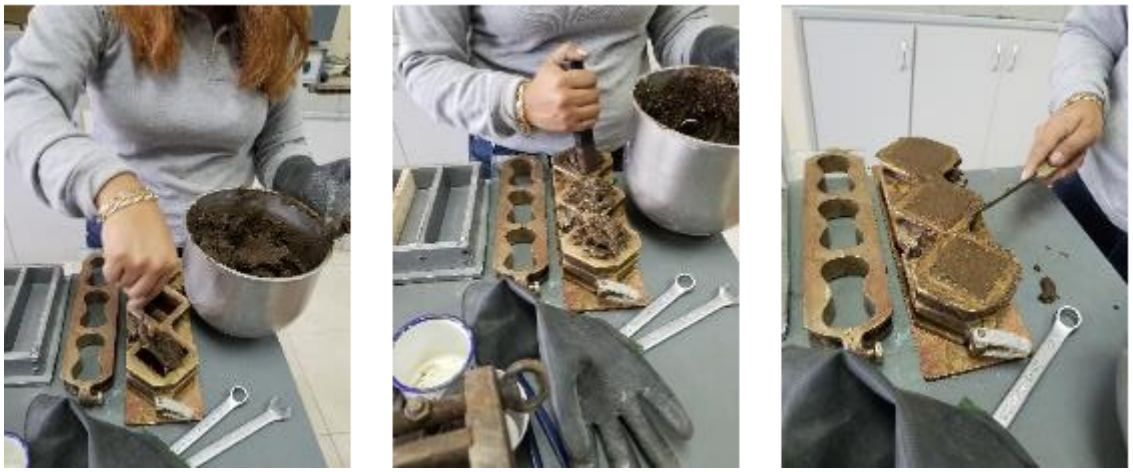

*Figure 14.* Mold filling process
*Note:* Source*:* Own elaboration, 2019

The results of the mechanical tests performed on each of the dosages were collected through direct observation and were recorded in Excel tables. Likewise, the necessary information was analyzed, interpreted, and obtained to arrive at the final result of each of the tests.

Subsequently, each of the results were analyzed to establish possible inconsistencies, errors, and correct them if necessary. All the information collected was carefully verified in order to write the final report of the tests recorded in standard forms of the soils laboratory of the Catholic University (PUCE).

***Mechanical laboratory tests***

To identify, determine the quality, and establish the best characteristics of the mortars, the specimens were subjected to the following mechanical tests in the laboratory:

Compression. - fm=P/A

Compression testing of the mortars was performed in accordance with ASTM C109: *Standard Test Method for Compressive Strength of Hydraulic Center Mortars (using 2-in. or [50-mm] Cube Specimens).*

For each mortar, three specimens per dosage were prepared for each breaking age. Three units per model were broken, obtaining three resistance records. The average between the three values obtained for each age of breakage was made in order to perform an analysis of the characteristics of each specimen.

*Figure 15.* Compression test specimens

*Note:* Source*:* Own elaboration, 2019

*Figure 16.* Schematic of compression rupture test.

*Note:* Source*:* Own elaboration, 2019

Tension/Traction. - RT=50*Max Load/Cross-sectional Area

Tensile tests were performed on the new dosages under AASHTO T132: *Standard Method of Test for Tensile of Hydraulic Cement Mortars.*

For the determination of the mortar's tensile strength, as in the other tests, three samples were used per dosage for each age of rupture proposed, with the strength data obtained from each sample. The average of the three values obtained from each sample analyzed was taken to evaluate its characteristics.

*Figure 18.* Tensile test specimens

*Note:* Source*:* Own elaboration, 2019

Figure 19. Tensile stress rupture test scheme.

*Note:* Source*:* Own elaboration, 2019

Bending. - K ring=3.43 kg/1/10000

Flexural tests were performed in accordance with AST C348: *Standard Test Method for Flexural Strength of Hydraulic - Cement Mortars.*

The execution of the tests to establish the flexural strength of the new dosages were also carried out with three specimens for each mix for the programmed breaking ages. For each period, three specimens were tested and their results were recorded and the arithmetic mean was calculated with their values, which are used to evaluate their characteristics.

*Figure 21.* Flexure test specimens

*Note:* Source*:* Own elaboration, 2019

*Figure 22.* Schematic of flexure rupture test.

*Note:* Source*:* Own elaboration, 2019

## Results

In the laboratory research process, the mechanical characteristics of the mortars were demonstrated by means of compressive, tensile, and flexural strength tests for each new dosage analyzed, according to the methodology proposed in the research. Results were obtained for the strengths of the three new dosages at ages of 14, 21, and 56 days; according to the established test times, it can be established that the three dosages present an ascending behavior in their strength in relation to the age of the test.

The compressive test data are recorded in a table of average results by age of rupture in which it can be observed that dosage 1 has a better compressive strength at 56 days, followed by dosages 2 and 3. However, at the age of 14 and 21 days, its compressive strength is lower than the other dosages. Nevertheless, it can be seen that dosage 3 at 14 and 21 days has a higher compressive strength.

Table 6
*Table of Compressive Strength Test Results*

| Compression Test Results | | | | | |
|---|---|---|---|---|---|
| Dosage N 1 B:C:N:P (7:1:2:1%) | | Dosage N 2 B:C:N:P (6.5:1.5:2:1%) | | Dosage N 3 B:C:N:P (6:2:1:1%) | |
| Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) |
| 14 | 0.30 | 14 | 0.35 | 14 | 0.46 |
| 21 | 0.44 | 21 | 0.53 | 21 | 0.55 |
| 56 | 0.68 | 56 | 0.62 | 56 | 0.59 |

*Conversion factor: 1 Mpa = 10.2 Kg/cm$^2$

*Note:* Source*:* Laboratorio de materiales PUCE, 2020

With the data obtained from the analysis, an average of these values is made with which each of the dosages is plotted to determine the resistance curve of each model. Figure 17 shows how the increase in compressive strength develops according to the age of rupture of each sample. Considering the 3 dosages, it can be shown that at 14 days of age there is an upward increase in which dosage 3 maintains the highest strength with 0.46 (Mpa). Similarly, in the breakage of the samples at the age of 21 days, there is also an increase in the resistance where dosage 3 has the highest resistance with a reading of 0.55 (Mpa); in the final test of the three dosages at 56 days of age, according to the data obtained in the readings, the highest resistance is presented by dosage 1 with 0.68 (Mpa), and the lowest resistance is presented by dosage 3 with a value of 0.59 (Mpa).

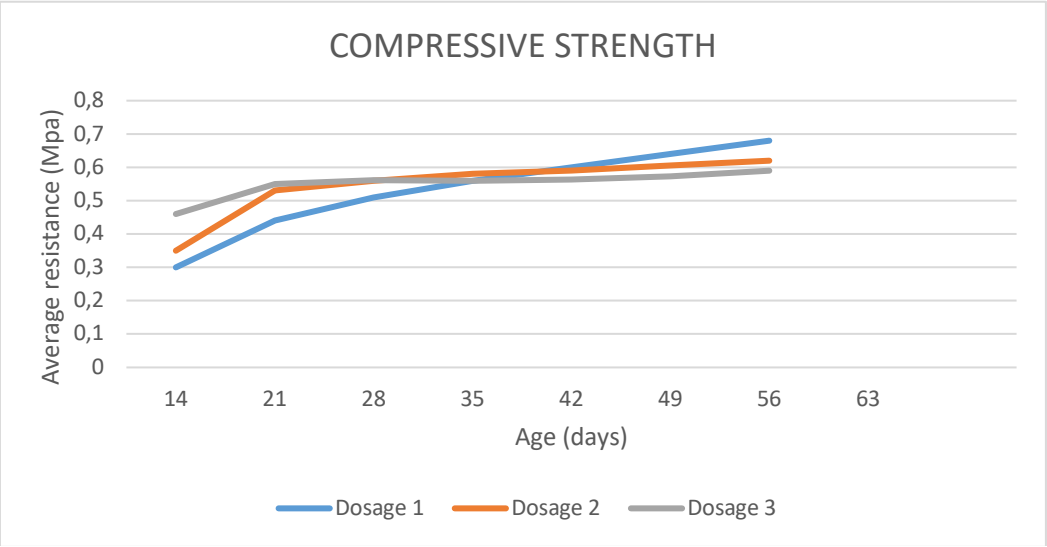


*Figure 17.* Table of test results Compressive strength
*Note:* Source: Laboratorio de materiales PUCE, 2020

With the values obtained from the tensile test, the table of resistance results was prepared. Consequently, the values obtained are analyzed comparing the dosages; thus, we have that sample 2 maintains higher tensile strength at the age of 56 days in dosage 3, followed by dosage 2. However, at the age of 14 days, the tensile strength is lower than the other samples. Nevertheless, it can be estimated that dosages 2 and 3 at 14 and 21 days of age present equal value of resistance, surpassing the value of the tension maintained by dosage 1.

Table 7

*Table of Tensile Strength Test Results*

| **Tensile Test Results** | | | | | |
|---|---|---|---|---|---|
| Dosage N 1 B:C:N:P (7:1:2:1%) | | Dosage N 2 B:C:N:P (6.5:1.5:2:1%) | | Dosage N 3 B:C:N:P (6:2:1:1%) | |
| Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) |
| 14 | 0.0100 | 14 | 0.0198 | 14 | 0.0198 |
| 21 | 0.0157 | 21 | 0.0220 | 21 | 0.0220 |
| 56 | 0.0197 | 56 | 0.0243 | 56 | 0.0258 |

*Conversion factor: 1 Mpa = 10.2 Kg/cm$^2$

*Note:* Source: Laboratorio de materiales PUCE, 2020

For a better appreciation of the results obtained in the mechanical tensile test, they are analyzed graphically. Figure 20 confirms the behavior of the samples in the resistance test based on the study carried out on the specimens at the corresponding age of rupture. The first analysis carried out on the 3 dosages was at the age of 14 days. Here it can be seen that there is an upward increase in their values. Dosage 1 has a resistance of 0.0100 (Mpa); thus, being the lowest and that the mixture with the highest resistance is 3, presenting a resistance of 0.0198 (Mpa). In the analysis carried out on the samples at 21 days of age, it can be seen that dosage 1 has the lowest resistance with 0.0157 (Mpa), but an increase in resistance can be noted in mixes 2 and 3, where a constant value is maintained between these two mortars with a resistance of 0.0220 (Mpa). In the experimentation at 56 days of age, the 3 dosages present ascending data, as can be observed in its result. The lowest resistance is presented by dosage 1 with 0.0197 (Mpa); contrary to this, the one that presents the highest resistance is dosage 3 with 0.0258 (Mpa).

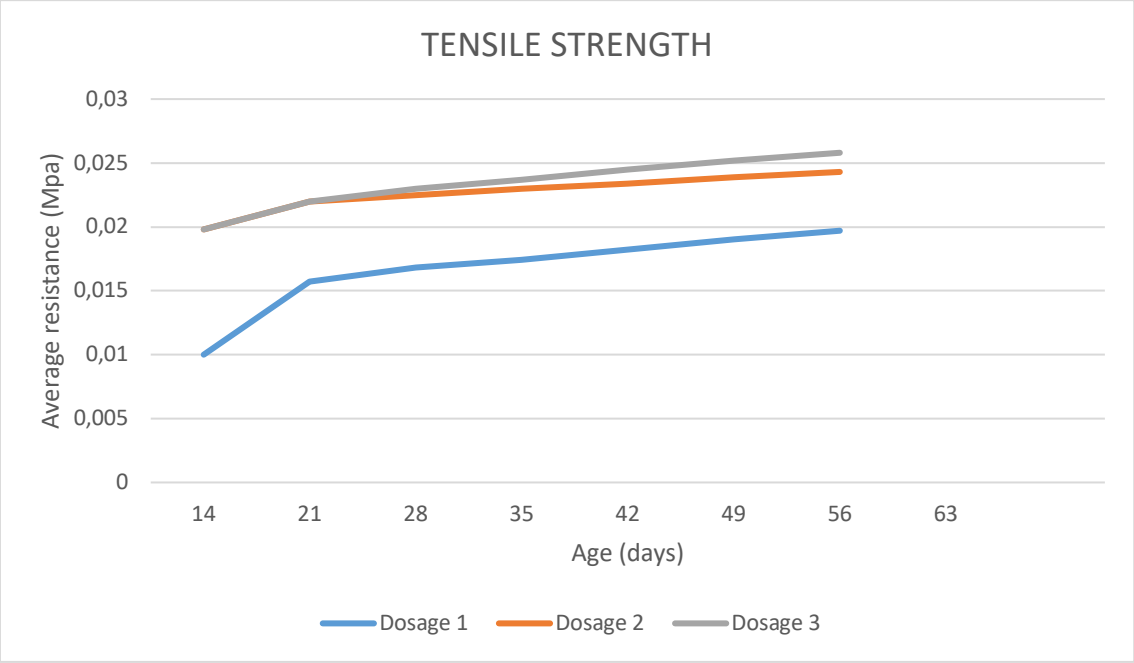


*Figure 20.* Table of Tensile Strength Test Results
*Note:* Source: Laboratorio de materiales PUCE, 2020

With the results achieved in the test with the mortars in the flexural tests, it can be established that dosage 2 shows a higher resistance at the age of 56 days, followed by dosages 3 and 1. However, at the age of 14 and 56 days, its resistance to flexure is the lowest in relation to the other dosages. Nevertheless, it can be observed that dosage 1 at 14 and 21 days of age shows a higher resistance.

Table 8
*Table of Flexural Strength Test Results*

| **Flexural Test Results** | | | | | |
|---|---|---|---|---|---|
| Dosage N 1 B:C:N:P (7:1:2:1%) | | Dosage N 2 B:C:N:P (6.5:1.5:2:1%) | | Dosage N 3 B:C:N:P (6:2:1:1%) | |
| Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) | Age (days) | Resistance Average (Mpa) |
| 14 | 0.147 | 14 | 0.124 | 14 | 0.084 |
| 21 | 0.151 | 21 | 0.141 | 21 | 0.114 |
| 56 | 0.169 | 56 | 0.249 | 56 | 0.193 |

*Conversion factor: 1 Mpa = 10.2 Kg/cm$^2$

*Note:* Source: Laboratorio de materiales PUCE, 2020

For a better interpretation of the results, these are represented graphically. Figure 23 shows the results of the analysis performed on the samples that were subjected to the flexural tests carried out at the test ages programmed for their rupture.

The initial analyses were carried out at 14 days. These results allow us to show that the values have a descending development, where it can be seen that dosage 1 has the highest resistance of 0.147 (Mpa), followed by dosage 2, which has a resistance of 0.124 (Mpa). It can also be observed lower data that present a lower resistance, and it is presented by dosage 3 with 0.084 (Mpa). In relation to the analysis made to the samples at the age of 21 days, it is also evidenced that the breakage at 14 days dosage 1 maintains the highest resistance with 0.151 (Mpa). On the other hand, dosage 2 shows a decrease in its resistance at 0.141 (Mpa), and the lowest resistance is presented by dosage 3 with 0.114 (Mpa). Likewise, in the experimentation carried out at 56 days of age, the data maintain an upward trend, the lowest resistance corresponds to dosage 1 with 0.169 (Mpa), while the highest resistance is given by dosage 2 with 0.249 (Mpa); whereas the average estimated resistance is given by dosage 3 with 0.193 (Mpa) (PUC, 2020).

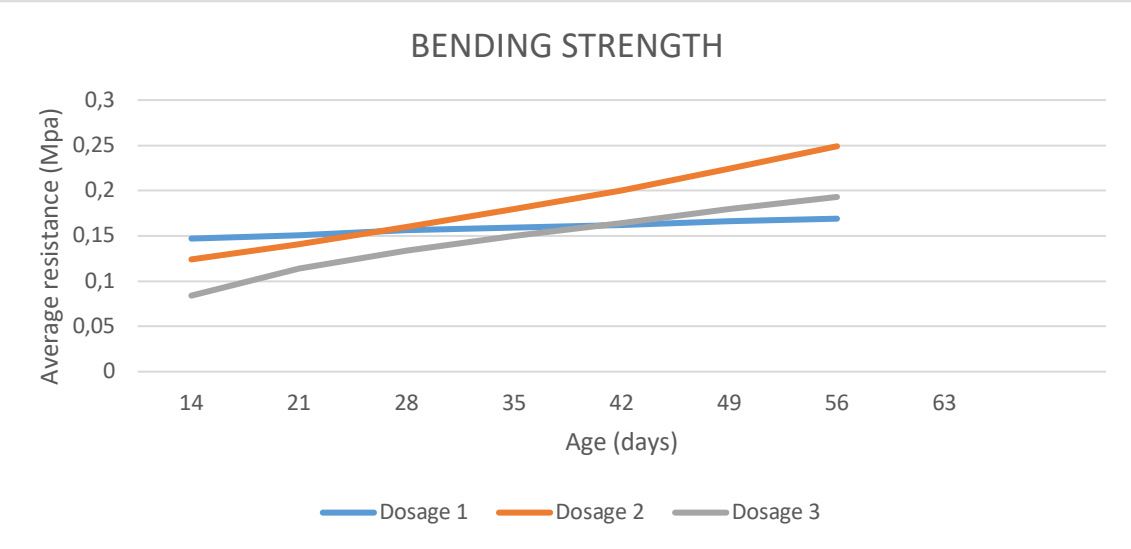


*Figure 23.* Table of Flexural Strength test results.

*Note:* Source: Laboratorio de materiales PUCE, 2020

In summary, dosage 1 has a higher compressive strength at 56 days, followed by dosage 2, while dosage 3 has a higher compressive strength at 14 and 21 days. Dosage 2 presents at 56 days a higher flexural strength, while at 14- and 21-days dosage, 1 has a higher flexural strength followed by dosage 2. Dosage 3 at 56 days has a higher tensile strength, followed by dosage 2, while at 14- and 21-days, dosage 2 presents a similar tensile strength.

From the results obtained, it can be determined that dosage 2, according to the values reached, which correspond to a mathematical average of the resistances with respect to the other dosages analyzed, presents better mechanical properties, being the optimum for application in restoration processes.

Table 9

*Table of results dosage 2*

| Dosage N 2 B:C:N:P (6.5:1.5:2:1%) | | | | | | |
|---|---|---|---|---|---|---|
| Age (days) | Compressive Strength | | Tensile Strength | | Flexural Strength | |
| | (Mpa) | Kg/cm$^2$ | (Mpa) | Kg/cm$^2$ | (Mpa) | Kg/cm$^2$ |
| 14 | 0.35 | 3.57 | 0.0198 | 0.20 | 0.124 | 1.26 |
| 21 | 0.53 | 5.41 | 0.0220 | 0.22 | 0.141 | 1.44 |
| 56 | 0.62 | 6.32 | 0.0243 | 0.25 | 0.249 | 2.54 |

*Conversion factor: 1 Mpa = 10.2 Kg/cm$^2$

*Note:* Source: Laboratorio de materiales PUCE, 2020

## Conclusions and recommendations

Once the experimentation was concluded, it can be determined that the three new dosages studied present very similar properties in relation to the research carried out on the tests of mechanical resistance to compression, tension and flexion applied to the mortars elaborated in the laboratory, after having analyzed the tests at the programmed ages of 14, 21, and 56 days in the laboratory, it can be considered that the results obtained are reliable.

On the basis of this study, it is intended to establish new guidelines for the use of traditional techniques and materials, so that they can be applied in heritage restoration processes and avoid the use of contemporary materials that alter and damage heritage monuments. In addition, this research is established as a starting point for further research with new dosages of traditional materials.

Mortars based on traditional materials are irreplaceable in an architectural restoration process since they are even the solution to structural problems for the protection of adobe, adobe, brick, or stone masonry. These mortars allow buildings to recover their integrity.

Research should continue on the properties of mortars with traditional materials, producing variations between each one of them. From these modifications, it is possible to obtain quantified mechanical properties that determine the quality of the mortars.

Given that the aggregate varies from one site to another, and, therefore, it has a notable influence on traditional mortars. This means that in each restoration project a study of the quality of the clay to be used in the elaboration of new mixtures must be carried out.

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**Receipt date:** 10/26/2021
**Revision date:** 11/04/2021
**Acceptance date:** 02/02/2022