PDM
PROJECT DESIGN & MANAGEMENT

Project Design and Management

MONOGRÁFICO

SPECIAL ISSUE - ABRIL 2023

PROJECT, DESIGN AND MANAGEMENT
Monográfico ● 2023
https://www.mlsjournals.com/Project-Design-Management

EQUIPO EDITORIAL / EDITORIAL TEAM / EQUIPA EDITORIAL

SUMARIO ● SUMMARY ● RESUMO

Editorial

This issue of MLS Project Design & Management emphasizes the importance of joint participation that connects with the diverse scientific disciplines of our collaborators. Innovation in scientific-technological development is a fundamental feature that demonstrates the main objectives of the journal in research and dissemination. This edition presents 8 selected articles. The teaching section presents two articles describing methodologies and tools for project management in education-related topics, demonstrating the importance and need to implement updates and new methods to promote the right to education and access to it. In addition, for the civil engineering and architecture branch, two relevant investigations are presented, the first one corresponds to the analysis of materials manufactured on site detailing their resistance, cost and deformation and the second one oriented to future developments in geotechnical engineering. The Project Management section presents research describing the timely development of engineering megaprojects in Brazil and the proposal of research projects as instruments of analysis for public policies, respectively. Finally, this issue presents kinetic modeling in the production of polyhydroxyalkanoates using Bacillus megaterium.

The first article demonstrates the effectiveness of systemic inquiry through continuous improvement of project management tools, applied and validated at the Universidad Estatal a Distancia (UNED), Mexico, providing emerging opportunities for improvement as a valuable characteristic of the systemic inquiry process.

The content of the second article, which shows a quantitative research, reflects the importance of the work carried out in the educational field on children's rights and access to the first stage of basic education, the methodology was implemented in the state of Mato Grosso-Brazil as part of the last year of the National Education Plan.

The analysis of ecological bricks presented in the third article shows that this material is able to deform and continue receiving loads, unlike traditional bricks that reach their maximum resistance without major deformation, allowing buildings to have greater elastic behavior and reducing some structural failures.

The fourth article, directed to geotechnical and architectural issues in the city of Mar del Plata in Argentina, establishes differentiated geotechnical characterization zones using a quantitative-qualitative methodology and systematization on a Geographic Information System (GIS), with interpretative and descriptive analysis of the structure.

The methodology implemented in the fifth article by applying a method of schedule analysis - the FORTE v Method. 1.0 - responsible for the first integrated initiative aimed at compliance, project management and corporate knowledge, adjusted to the reality of large engineering projects in Brazil, resulting in the optimization of project management and organizational hierarchy.

Through an application case that analyzes research projects as public policy instruments, the sixth article details the theoretical relevance of the research, allowing to contribute conceptual contents from an interdisciplinary approach in the field of culture in the analysis of public policies.

The seventh article focuses its research on the development of soft skills of engineering students through a collaborative work model, the results indicate the importance of including

in their work placements, effective communication, negotiation, empathy and leadership as necessary skills in the world of work.

Finally, the eighth article proposes a first stage of using mathematical simulation models for the kinetics applied in the production of microbial polyhydroxyalkanoates, demonstrating that bacteria can be isolated from the humus of the Californian red worm, and for the growth of biomass a logistic model is used that includes an inhibition factor and a constant associated with cell maintenance.

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, as well as the Iberoamerican University Foundation (FUNIBER) and the Universities that have provided all the material support 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
Dr. Roberto M. Alvarez
Editors-in-Chief

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:
Quesada Brenes, E. & Segura Castillo, A. (2023). Indagación sistémica para la mejora continua de las herramientas de gestión de proyectos: El caso gestiona de la Universidad Estatal a Distancia. *Project, Design and Management,* número monográfico, 7-26 . 10.35992/pdm.mo2023.1826.

SYSTEMIC INQUIRY FOR CONTINUOUS IMPROVEMENT OF PROJECT MANAGEMENT TOOLS: THE GESTIONA CASE OF THE STATE DISTANCE UNIVERSITY

Esterlyn Quesada Brenes
Universidad Estatal a Distancia / Universidad Internacional Iberoamericana (Costa Rica)
equesada@uned.ac.cr - https://orcid.org/0000-0002-3426-6515
Andrés Segura Castillo
National High Technology Center / Open University / Universidad Estatal a Distancia, University of Costa Rica (Costa Rica)
asegurac@uned.ac.cr - https://orcid.org/0000-0001-5647-1176

Summary. The Research System of the Universidad Estatal a Distancia (UNED) has sought, since its creation, to promote a systemic dynamic for the management of its projects, supported by customized technological tools. This perspective challenges the traditional view of research project management and opens up possibilities for innovation in this area. Thus, Gestiona, an online software for capturing the information produced by the projects belonging to this research system, was created. The objective has been the continuous improvement of Gestiona and its adaptation to the changes of the UNED research system, considering as an effectiveness criterion the minimum possible loss of information from the data generated by the projects. This paper shows how a systemic investigation of the behavior of the actors involved in the projects has allowed the continuous improvement of the tool and the capture of relevant data in Gestiona, for decision making by the managers of the research projects. The results obtained show the effectiveness of systemic inquiry as an alternative for the continuous improvement of project management. Emerging opportunities for improvement are also presented as a valuable feature of the systemic inquiry process.
Key words: systemic inquiry, continuous improvement, Gestiona, UNED

INDAGACIÓN SISTÉMICA PARA LA MEJORA CONTINUA DE LAS HERRAMIENTAS DE GESTIÓN DE PROYECTOS: EL CASO GESTIONA DE LA UNIVERSIDAD ESTATAL A DISTANCIA

Esterlyn Quesada Brenes
Universidad Estatal a Distancia / Universidad Internacional Iberoamericana (Costa Rica)
equesada@uned.ac.cr · https://orcid.org/0000-0002-3426-6515
Andrés Segura Castillo
Centro Nacional de Alta Tecnología / Open University / Universidad Estatal a Distancia, Universidad de Costa Rica (Costa Rica)
asegurac@uned.ac.cr · https://orcid.org/0000-0001-5647-1176

Resumen. El Sistema de Investigación de la Universidad Estatal a Distancia (UNED) ha buscado, desde su creación, propiciar una dinámica sistémica para la gestión de sus proyectos, apoyada en herramientas tecnológicas diseñadas a la medida. Esta perspectiva reta la visión tradicional de gestión de proyectos de investigación y abre posibilidades de innovación en este ámbito. Así, surge Gestiona, un software en línea para la captura de la información producida por los proyectos pertenecientes a dicho sistema de investigación. Como objetivo se ha buscado la mejora continua de Gestiona y su adaptación a los cambios del sistema de investigación de la UNED, considerando como criterio de efectividad la mínima pérdida de información posible a partir de los datos generados por los proyectos. El presente trabajo muestra cómo, una indagación sistémica del comportamiento de los actores que intervienen en los proyectos, ha permitido la mejora continua de la herramienta y la captura de datos relevantes en Gestiona, para la toma de decisiones por parte de las personas gestoras de los proyectos de investigación. Los resultados obtenidos muestran la efectividad de la indagación sistémica como una alternativa para la mejora continua de la gestión de proyectos. Asimismo, se presentan oportunidades de mejora emergentes como una característica valiosa propia del proceso de indagación sistémica.
Palabras clave: indagación sistémica, mejora continua, Gestiona, UNED

Introduction

The Research System of the Universidad Estatal a Distancia (UNED) has sought, since its creation, to promote a systemic dynamic for project management mediated by technological tools tailored to the institution. This vision represents, in addition to a challenge, given the context of scarce Costa Rican public resources, a space for the creation of new forms for the management of research and innovation projects that nourish the dynamics of the UNED research system.

In order to guarantee the quality of its research, innovation and development initiatives, with its own inputs and under the leadership of a team of university researchers with experience in systems analysis and development, an online software tool was built, which for several years would be hosted on a computer with minimal resources, purchased with funds earmarked for research.

It was called Gestiona and in a short time, related to the task of supporting project management and strategic decision making, it was also designed to be the window to make UNED's research visible to the whole world, a task it has carried out up to the present.

Based on a systemic investigation of UNED's research work, Gestiona has continuously adapted to the behavior of UNED's research system processes, considering as an effectiveness criterion the minimum possible loss of information from the data generated by the projects.

Systemic inquiry is conceived as a social learning process, focused on addressing a complex situation of interest, where actors with multiple perspectives participate, there are changing environments and diverse technological elements, in order to propose improvement actions for it (Ison, 2017). This approach is based on the idea that systems cannot be fully understood by examining their parts individually, but that it is necessary to understand how the parts interact with each other and how these interactions give rise to the complexity of the system as a whole.

It involves the use of various tools and techniques to analyze complex systems, including mathematical modeling, simulation, network analysis, data visualization and participant observation. In addition, it uses an iterative approach to research, in which the results obtained are used to adjust and refine the understanding of the system in question.

This approach has been used in multiple fields, such as biology, ecology, economics, sociology, psychology and engineering, among others. It is considered especially useful for dealing with complex and multidisciplinary problems.

Thus, systemic inquiry has 4 components:

- Situation of interest: The situation to be explored in order to find possible alternatives for improvement. It is assumed that it is perceived as complex by stakeholders, i.e., it involves multiple actors with possibly conflicting perspectives, it occurs in a changing environment and its solution is not formalizable (Rittel & Webber, 1973).
- Practicing person: In this case, it is the members of the consulting team who guide the development and implementation of the systemic inquiry, using different tools from the systemic tradition to understand and address the situation of interest (Blackmore, 2010).
- Framework: The theoretical reference that guides the selection of methods and techniques to be used during the systemic investigation of the situation of interest.
- Set of methods and techniques: In accordance with the stated framework, a series of techniques or methods to be used are defined. These can be qualitative, quantitative or mixed.

However, before going deeper into the results of the systemic inquiry applied to the Gestiona system, it is important to clarify important aspects of the context and the situation of interest perceived as problematic.

In the first instance, it is worth noting that the development of Gestiona emerged from researchers belonging to the UNED research system, with a more proactive and risk-taking vision than that of the traditional management in charge of institutional technological development, which tends to be slow and not very open to innovation processes.

It is not common for researchers (even if they have a background in computing) to develop and be in charge of taking care of the necessary modifications to a computer system, so, although there are multiple methodologies of analysis and design of requirements that could be applied to the process of continuous improvement, it was decided to give an investigative approach to the evolution of the system itself, thus causing the users to eventually be direct actors in the process of change.

Gestiona was conceptualized in a complex environment, where there were phenomena that predicted that it would not be a usual development. These phenomena, which at the beginning were considered obstacles, were solved thanks to the visionary decisions made by the person who was vice rector at the time and the work team of programmers-researchers in charge of the task, and were transformed into opportunities that would differentiate it from the rest of the institutional systems to this day.

The phenomena referred to are:

- The short time elapsed in management: the Vice Rector's Office for Research was created in 2007, therefore, at the beginning of the development of Gestiona (2011) the macro-processes and processes were just beginning to be conceptualized, which encouraged a previous exploration to conceptualize the system, making it the product of a research project in itself.
- The existing dilemma between the UNED's Vice Rector's Office for Research and the Directorate of Technology (DTIC): the alternatives offered by the latter in terms of innovation and response time did not satisfy the Vice Rector's authority and, therefore, technological independence was chosen, which would include constant experimentation with new practices and tools.
- Trying to pigeonhole the new tool to meet the need to support research management, within the parameters requested by the DTIC, since it was necessary to have clearly identified all forms, processes and reports, contrary to the intention of keeping the system always open to improvements, in response to the changing work dynamics of the UNED research system.
- The multidisciplinary nature of the system's users: Gestiona would be used by biologists, philosophers, psychologists, professors, theologians, teachers and many others, which meant that the tool had to be perceived as simple, flexible and intuitive, but above all, that it would not hinder research.
- Resistance to change: being born in an abstract environment, as the research system was in its beginnings, meant that many researchers were opposed to its development. For example, it was considered a mistake to delimit the start and end date of projects by advocating terms such as transversality over time.
- The existence of multiple project executors: anyone can carry out research at UNED, regardless of whether they do it individually or in groups, and the administrative or academic unit of the participants is indifferent. This leads to the existence of a normal rose between the different forms of project management, which is reflected in the diversity of presentation forms, letters of endorsement from external peers, and progress and closure report templates. So, Gestiona had to be tolerant in terms of the formats of the stored documents.
- Likewise, the presence of multiple entities sponsoring research projects, mainly governmental institutions, as well as international organizations, required researchers to fill out the project presentation template defined by each entity. Therefore, if an additional step was added to the process to require the completion of another document with the format defined by the Vice Rector's Office for Research, it would have been a bad strategy to seek the acceptance of Gestiona.

Thus, from the beginning, the development of Gestiona as a tool for capturing information resulting from the dynamics of research projects, was surrounded by an environment with a certain resistance to change, a situation that demanded a different approach, which in addition to subsisting in the midst of such complexity, would promote continuous improvement for a successful adaptation to the changes and demands that would eventually arise in the environment.

Continuous improvement, according to Garcia Medina et al (2018) will result in an improved product or service, more competitive and much more responsive to customer requirements, where through a systematic approach, processes are identified, analyzed and improved in terms of quality, efficiency and effectiveness. This process is carried out through

the following steps: 1) problem identification, 2) problem analysis, 3) solution development, 4) solution implementation, 5) monitoring and measurement, and 6) continuous evaluation.

This paper shows how a systemic inquiry that considers the actors involved in the projects has allowed the continuous improvement of the tool and the capture of missing data in Gestiona, to facilitate decision making by the managers of the research projects. The methodology implemented during the systemic inquiry is detailed below.

Methods

One of the components of systemic inquiry is the choice of a framework that defines the techniques or methods to be used, whether qualitative, quantitative or mixed. In our case, we adopted the Soft Systems Methodology (SSM) (Checkland & Poulter, 2010), which promotes the search, with the support of various tools such as scatter diagrams, enriched images, among others, of spaces for improvement based on the dialogue between the parties involved and the generation of commitments that lead to feasible and viable actions in the context.

The SSM methodology was developed in the 1970s by British researcher Peter Checkland and has been used in various fields such as business management, urban planning and education, among others, since its approach is to solve complex problems involving social or human systems, rather than technical or mechanical systems.

Its application was considered because work sessions can be carried out using generative questions, scatter diagrams, enriched images, activity models, among others, in order to understand and address the situation of interest. According to Ison (2017), these tools become useful cognitive devices for stakeholders to share their requirements and reach workable consensuses for the resolution of the situation of interest.

In the case of the evolution of Gestiona, from its implementation to date, systemic inquiry has been used every time a problem or an opportunity for improvement has arisen, following the cycle shown below:

1) Identification of relevant stakeholders: At this stage, the relevant decision makers in the context of the situation of interest were identified. This identification process was based on the selection criteria of people with active support roles in the management of research projects, researchers, students and authorities.

2) Discussion sessions: Discussion sessions guided by the main concerns were designed to identify the various perspectives on the problems or opportunities for improvement. Enriched imagery was used to facilitate understanding of the perceived problematic situation (Bell et al., 2016).

3) Search for compromises: Through discussions guided by the results obtained, the participants were guided to visualize possible agreements for the generation of commitments towards viable future actions.

4) Definition of viable actions to follow: Through dialogue, viable actions were prioritized and defined to improve the situation perceived as a problem or opportunity for improvement.

The results obtained from the methodological steps described above are shown below.

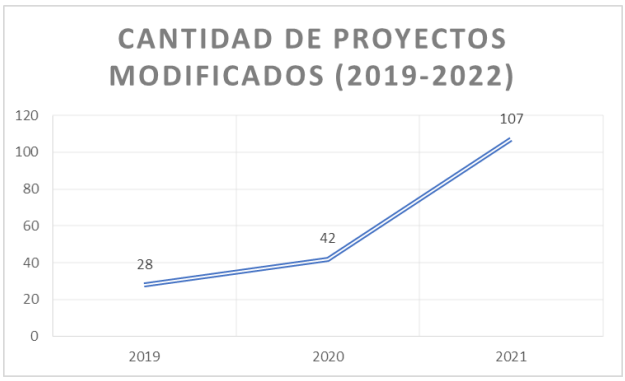
Results

The first result obtained from the systemic inquiry is the deconcentration of management in Gestiona. It was detected, given the convergence of the actors during the investigation, that each project executing agency within the research system used its own tools to maintain a list of its projects, with information that was not necessarily entered into Gestiona. At the same time, it was identified that most of the units had human talent dedicated to the management of their projects and the corresponding documentation, so it was considered an opportunity to implement a new role in the system, called Unit, which would allow the registration of the information of their own research projects, without the intervention of the personnel of the vice-rector's office.

The following figure shows how, as a result of this change, the number of updates to projects increased by 73%, contributing to the reduction of information gaps that prevented adequate decision making based on Gestiona data.

Figure 1

Number of modified projects (2019-2022) in the Gestiona system

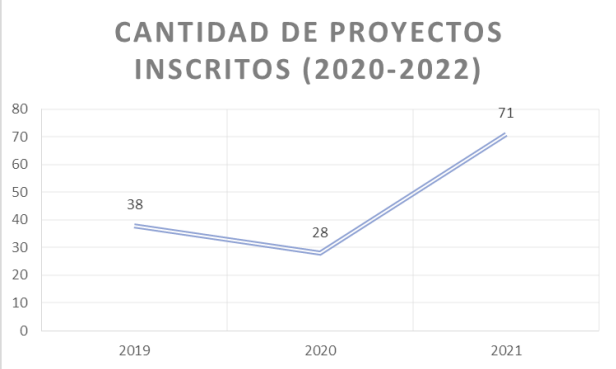


Note. Source: own elaboration using system traceability data

It should also be added that as a result of the systemic inquiry, the creation of the role was accompanied by individual training for each unit and in those that decided to use the new profile, a thorough cleaning of the data of the existing projects and the registration of the missing projects was achieved. Figure 2 shows that the number of self-managed projects, i.e., those entered into the system by persons in charge of the different units, increased from the second year onwards.

Figure 2

Number of projects registered with the role of Unit (2019-2022) in the Gestiona system



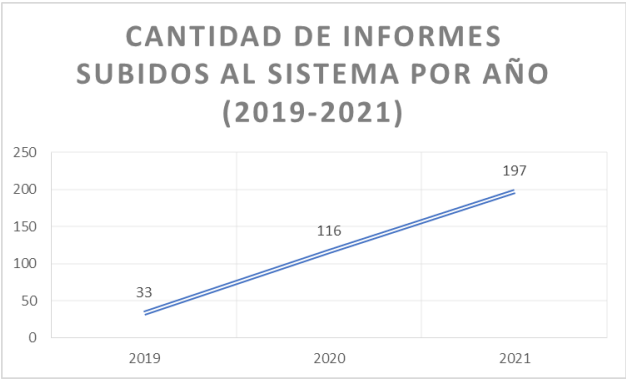
Note. Source: own elaboration using system traceability data

Another result was the automatic inactivation of projects in the system. Here, where the participants in the survey were mainly researchers with projects registered in Gestiona, they acknowledged their carelessness in not sending the progress or closure reports to be uploaded to the system, even though they did submit them to their respective units. On the other hand, it became evident that those in charge of updating the data in the system from each unit were not taking on the task of attaching the reports submitted to them. The solution proposed by the users themselves was that the system would automatically change the status of the projects to inactive if more than 6 months had elapsed since the last time a progress report was attached.

The results of having implemented the solution described above are shown in Figure 3, showing that the number of reports uploaded to the system tripled in the first year and grew almost 6 times in the second year.

Figure 3

Number of reports uploaded to the system per year (2019-2022)



Source: own elaboration using system traceability data

Continuing with the results obtained from the systemic inquiry, the need arises to geo-reference the activities carried out in the different research projects. The justification for this requirement, which was raised by the users themselves, is that the location indicated at the time of requesting the registration of a project, was mostly that of the unit or office to which it is presented and from where the resources are allocated, both in time (time dedicated to research)

and money (travel expenses mainly), however, this location does not reflect the day-to-day dynamics and what is really experienced in the development of the research, since the tasks are carried out in practically all the national territory, for example, to take samples, interviews, observations, prototype tests, among others. Thus, the functionality of the system was developed to allow the registration of activities, independent of each other, but linked to the same project and that each one could be geo-referenced. This point, rather than reacting to a detected problem, emerges as an innovation that provides added value to Gestiona, not only to the actors that participate in the dynamics of the UNED research system, but also to external entities that wish to access the information. The image below shows how the geo-referenced activities are displayed in the system.

Figure 4

Example of the display of georeferenced information in Gestiona

Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023)

Linked to the previous result, another need for consideration arose from user feedback. It involves attaching photographs to the activities carried out for a project. Nowadays it is commonplace that when we participate in meetings, workshops, trainings and other work activities, it is necessary to take at least one photograph of the work group, which is used to upload it to social networks or to save it as part of the evidence that the event was carried out. Well, this behavior was seen as an opportunity for improvement for Gestiona, by allowing the attachment of photographs related to the activities, which in themselves were already going to be registered in the system for the purpose of georeferencing the project.

Figure 5

Example the inclusion of photographs in the project activities in the Gestiona

Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023)

The following request corresponds to the need to track the requests made to the Vice Rector's Office for Research. The investigation revealed that there was uneasiness about the processing times of the procedures requested to the vice-rector's office, since the researchers did not receive adequate feedback on the current status or whether they had been received by the right person. The evidence presented showed that many requests were never answered, although the steps indicated were carried out, mainly those related to modifications of project or researcher data registered in the system. The solution proposed and eventually implemented was the possibility of making requests within the Gestiona system itself, and in this way, from the moment of entry to the final attention, the applicant could visualize the current status and the steps as he/she progressed through the flow of attention. The following figure shows part of the list of requests that have been attended within Gestiona, as a result of the implemented solution.

Figure 5

Example of how requests are handled in Gestiona

1 2 3 4 5

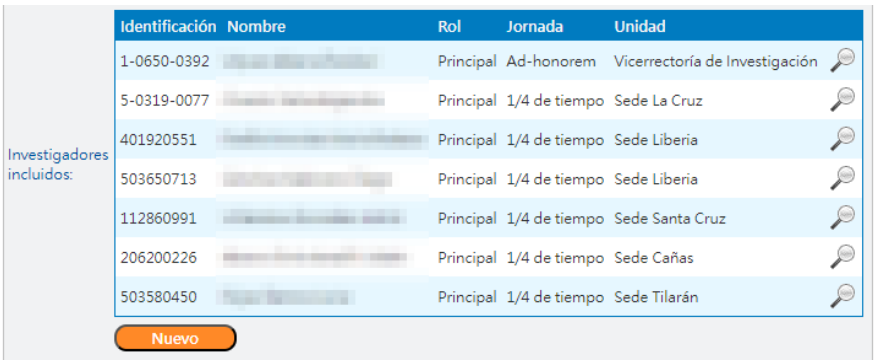
Leída	Código	Fecha	Investigador	Detalle	Estado
	150	28/02/2023	Vargas Sanabria Daniela	Título: El régimen de incendios en Costa Rica: pos	En revisión presupuesto
	149	09/02/2023	Artavia Díaz Karla Yanitzia	Con el paso del tiempo la visión tradicional de ed	Rechazada
	148	09/02/2023	Artavia Díaz Karla Yanitzia	Con el paso del tiempo la visión tradicional de ed	Atendida
	147	06/02/2023	Alfaro Fallas Tomás	Nombre completo: Diego Gerardo Bogarín Chaves. DNI	Atendida
	146	01/02/2023	Vargas Castro Luis Esteban	Buenas, quisiera amablemente solicitar el document	Atendida

Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023)

Thanks to the systemic inquiry, a common work dynamic was observed in the projects developed at UNED, but it was not so noticeable until the authorities emphasized that it should be made visible. This is the linking of personnel from different units to carry out a research project. This practice occurred mainly in the regional branches of the university that share the same region, hence the importance of taking into account researchers from all over the country in the research sessions with key actors. The solution proposed was the individual assignment of the unit to which each researcher who will be part of a project belongs, as shown in the following figure.

Figure 6

Example of the individual assignment of the researcher's unit in Gestiona

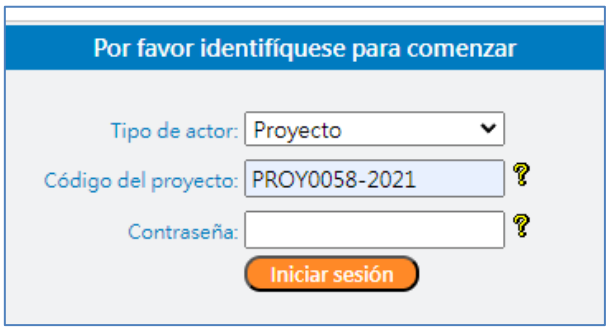


Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023)

Such was the effect of the decentralization of project administration in Gestiona when the Unit role was created, that the researchers requested the creation of a second role called Project. They saw the need to empower themselves in the management of their projects registered in the system and thus not depend on the personnel of the Vice Rector's Office for Research, nor on the unit to which it corresponds to present their project. This role would allow them to perform functions such as attaching documents to the file, registering geo-referenced activities and making modifications to the data they were allowed to make without affecting the data used for monitoring and control by the corresponding unit and the vice-rector's office. Thus, the Project role was incorporated, which provided access exclusively to the project information with the code indicated in the access.

Figure 7

Example of the screen to enter with the Project role in Gestiona

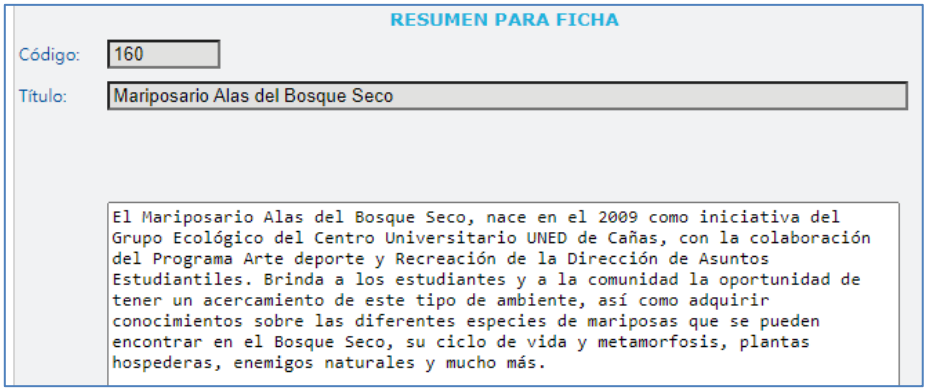


Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023).

Not only researchers and project management personnel have participated in the systematic inquiry, but other relevant actors have also been considered, such as the staff of the Scientific Dissemination Unit, who gave their opinion on improvements in Gestiona that could be useful for their assignments. Although several proposals were implemented, one of them whose need would hardly have been identified by the project management team of the Office of the Vice-Rector for Research is presented here. This was a space to enter into the system, a summary of the project that would be understandable to the general public. The summary had to be written in a simple vocabulary that could be understood even by children and young people. The idea was to use this text every time a dissemination event was organized, where the projects developed at UNED were presented. Figure 8 shows an example of a tab summary.

Figure 8

Example of a summary for the Gestiona® card



Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023).

To this day, this data continues to be used, even as input for management reports addressed to the authorities, since, as we have already pointed out, these texts should be understandable to the general public. The writing of these abstracts has since been a collaborative effort between the Scientific Dissemination Unit and the designers.

Although the Gestiona system was created to support project management, it has also served as a research tool. For example, at the request of a team of researchers, we proposed the incorporation of screens for the entry of complementary information from people doing

research at UNED, which was collected through interviews and questionnaires. We can see in Figure 9 that data on disabilities, number of children, illnesses, medications taken and allergies suffered were captured. This information is not traditionally handled in a project management system, but as explained above, most of the requirements have arisen from ongoing systemic inquiry and have also been supported by the ongoing authority of the vice chancellor's office and a technical team that makes the implementation of the changes possible.

Figure 9

Example of researcher health data in Gestiona

Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023).

So far, the requirements that have arisen from the constant systemic inquiry applied to the continuous improvement of Gestiona have been presented, but fortunately they could be solved in an agile way, thanks to the work dynamics of the Vice Rector's Office for Research, which allowed and encouraged this to be done. However, as we will see below, two of the improvement possibilities for Gestiona had to be conceptualized as projects due to their great magnitude with respect to the time required for their development and the need to carry out exhaustive tests to guarantee their correct operation.

The first example was the need proposed by the staff of the Office of the Vice-Rector for Research, who manage the budget for projects and other administrative procedures. The aim was to address a deficiency in the institutional accounting system that did not allow (and still does not allow today) an individual record of budget execution by project, nor does it allow the pre-allocation of amounts to projects at the beginning of the period, i.e., the vice rectory was a common pot from which resources were taken for all initiatives that were under development, causing the distribution to be inequitable and some project developers to be left without support if they were late in requesting it.

By sharing this possibility of improving Gestiona with other key players in the research system, the need arose to expand and consider the budgetary management of the research units themselves, not only for projects, since, for example, several units had their own allocated budget and used it to purchase equipment and materials that were used in various projects.

Thus, the system improvement project was defined to incorporate a budget module for projects and units, which would complement the existing institutional one, commonly known as AS400. Its development took several months and, like Gestiona itself, was carried out solely with resources from the Office of the Vice-Rector for Research. The following figure shows the menu that provides access to the various budget-related enhancements.

Figure 10

Example of the menu of the budget management module in Gestiona

Note. Source: Gestiona system, Vice-rector's Office for Research, UNED (2023).

The following is a final example of the results of applying the systemic inquiry methodology at UNED.

After working sessions with key personnel, the idea of having an application for mobile devices (App) emerged, which would respond to the demand of being able to access information from mobile devices and, as Torres-Salinas (2012) points out, this opens a field of infinite possibilities for research, being able to access scientific information services and serve as a tool for laboratory and field work. Figure 11 shows the main screen of the developed App.

Figure 11

Example of the Gestiona application for mobile devices

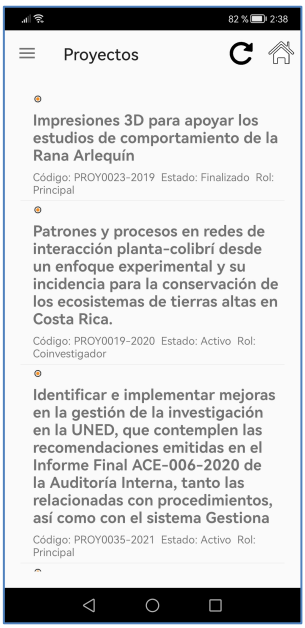
Note. Source: Gestiona application for mobile devices, Vicerrectoría de Investigación, UNED (2023).

Here the main discussion did not revolve around the development of the App as such, as it had sufficient support, but which functionalities of Gestiona should be accessible from mobile devices. These functionalities are described below, with details of the main benefits obtained.

1) Display the list of projects linked to the researcher who accessed from the App. Thanks to this list, shown in Figure 12, inconsistencies in the information were detected, which mainly involved people who were part of the work team of a project, but no official request was made for this relationship to be reflected in Gestiona.

Figure 12

Example of the project list accessed from the Gestiona App

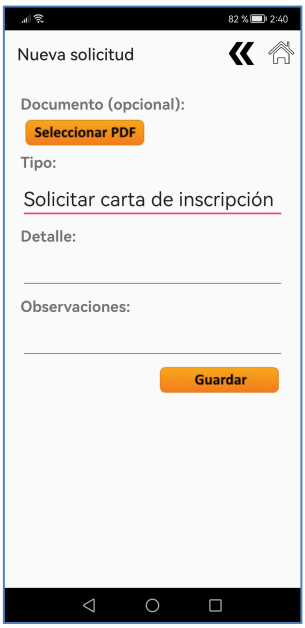


Note. Source: Gestiona application for mobile devices, Vicerrectoría de Investigación, UNED (2023).

2) Enter requests addressed to the Office of the Vice Chancellor for Research from the App. This feature allowed people to register a new application, at any time and in any place, from a mobile device, which was especially useful for those people who were constantly on the move and had to wait until they reached their office or home to use Gestiona from their web browser. The following figure illustrates the implemented solution.

Figure 13

Example of the screen to include a new request from the Gestiona App



Note. Source: Gestiona application for mobile devices, Vicerrectoría de Investigación, UNED (2023).

3) Record geo-referenced activities and photos related to the research projects. This is a complement to the previously described need for the system to maintain a list of activities, to which the geographic location where they were carried out could be defined, as well as to attach photographs to document the experience. It makes a lot of sense that, during or after the development of the activity and being at the site of the action, the activity could be recorded in the Gestiona, even more, if the photographs could be taken at the same time with the camera of the mobile device. This is how this feature was taken into account and included in the Gestiona App. The example is shown in the following image.

Figure 14

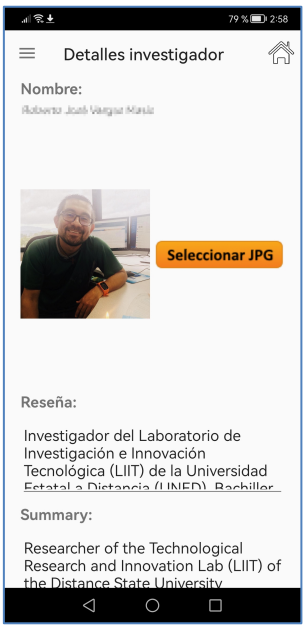
Example of the activity log screen from the Gestiona App

Note. Source: Gestiona application for mobile devices, Vice-rectorate of Research, UNED (2023)

4) The last feature of the Gestiona App, resulting from the application of the systemic inquiry methodology, is the possibility for the researchers to visualize their personal data from their mobile devices. Although this functionality did not seem to be innovative and that it would not cause a great impact among users, the truth is that, either out of curiosity or real interest, many people entered to verify their data (an action that could have been done from Gestiona since a long time ago) and this resulted in a large amount of updated information. The implemented improvement also allowed the update of the photograph from the mobile device, something that seemed to have been liked, as it was evidenced that many users updated it. This phenomenon may have been due to the fact that uploading a photograph from the App eliminated the additional step of first transferring it from the mobile device to the computer and then logging into Gestiona and uploading it.

Figure 15

Example of the self-managed researcher profile from the Gestiona App



Note. Source: Gestiona application for mobile devices, Vicerrectoría de Investigación, UNED (2023).

The conclusions obtained from the systemic inquiry for the continuous improvement of Gestiona are presented below.

Conclusions

Gestiona is a valuable case study as a technological tool that adapts to changes in the environment through systemic inquiry for the benefit of research project management. The results obtained, in addition to contributing to the improvement of the situation of interest, change the perception of the problem and open up new opportunities for improvement. This is an extremely valuable point of systemic inquiry that differentiates it from other possible methodologies, since the participating actors, in addition to presenting their demands or perspectives, approach different worldviews that appreciate the problematic situation from another perspective, seeking and achieving consensus agreements for improvement actions.

Having reached a satisfactory resolution of the cases shown, is a consequence of the constant application of the continuous improvement process for Gestiona, since every day needs and opportunities have arisen, thanks to the fact that the environment maintains an accelerated pace of change, which will probably increase complexity in the future and result in new situations perceived as problematic, as pointed out by Rittel & Webber (1973).

Although not included in this work, Gestiona has also responded to needs emanating from external actors to the research system, whose solution did not demand a systemic research as such, since they have been specific requirements and mandatory compliance, such as: incorporating the linkage of projects with the UN Sustainable Development Goals or classifying projects and researchers based on criteria requested by the National Commission of Rectors (CONARE), the Ministry of Science, Technology and Telecommunications (MICITT) or the Ministry of Health, mainly for the generation of research and development (R&D) indicators that are annually requested from UNED.

Numerous presentations and training sessions on Gestiona have been given to UNED units and other universities in Costa Rica, making it a benchmark as a successful research project management system.

Gestiona has had a great impact as data input for the generation of the institution's R&D indicators, reducing the time spent on this task from weeks to just hours, without losing the veracity and effectiveness of the information obtained. This is the result of having a system that does not centralize the administration of information, running the risk of becoming a bottleneck, but rather reflects the reality of the research work, with data coming directly from the participants.

As is normal in an academic environment where there is a constant questioning of new ideas and perspectives, Gestiona has not been free of detractors who discredit it as the optimal tool for the management of research projects, arguing that it does not allow adequate control and monitoring of the scope, time and cost of these. The truth is that Gestiona was born and evolved in response to the needs of an entire research system and not its separate parts. Those who do not find the tool useful are those who have not brought their requirements to the table at the right time, i.e., when it was their turn to participate in systemic inquiry tasks.

Linked to the above, there have been proposals to replace Gestiona as a working tool, however, most of the initiatives do not transcend and disappear in the stages of requirements gathering and solution development, because, as mentioned in this paper, there were several phenomena that surrounded the conceptualization of Gestiona and that forced to think about it in a very different way. Thus, the system was born under the premise that it would never be finished, but that its evolution would be constant, and for this purpose it was thought to permanently apply a methodology such as systemic inquiry, which would bring benefits such as: allowing the identification of underlying problems, improving decision making, fostering collaboration and helping to find effective solutions.

The needs and opportunities for improvement that Gestiona will have to face are endless, especially with the exponential growth of new technologies and their potential use for research. However, as long as Gestiona has the capacity to adapt to the changes that arise in the research system and the work team of the Vice Rector's Office for Research maintains the dynamics that have allowed this rapid adaptation, success will be guaranteed, especially if they rely on the use of methodologies such as systemic inquiry, which allows the involvement of key people and the identification of the next milestones to be reached for the benefit of the same people and the entire research system.

References

Bell, S., Berg, T., & Morse, S. (2016). *Rich pictures: Encouraging resilient communities*. Routledge.

Blackmore, C. (2010). Managing systemic change: future roles for social learning systems and communities of practice? In *Social learning systems and communities of practice* (pp. 201-218). Springer, London.

Checkland, P. & Poulter, J. (2010). In Reynolds, M., & Holwell, S. (Eds.). *Systems approaches to managing change: a practical guide*. Springer Science & Business Media.

García Medina, J. L., García Severino, A., & Sámano Quiroz, J. (2018). Control and optimization of manufacturing processes. *Revista Ciencia Administrativa*, 112-126.

Ison, R. (2017). *Systems Practice: How to Act: In situations of uncertainty and complexity in a climate-change world*. Springer London.

Ramage, M., & Shipp, K. (2009). *Systems thinkers* (pp. I-VII). Springer.

Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, *4*(2), 155-169.

Torres-Salinas, D. (2012). *Smartphone and mobile web applications in science and research: Applications of smartphones and the mobile web in science and research.* Think EPI Yearbook,

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:

Cadidé Vilela, M. & Queiroz de Morais, C. (2023). O acesso à educação infantil no estado de Mato Grosso-Brasil: ao final do Plano Nacional de Educação (2014-2024). *Project, Design and Management,* monographic issue, 27-36. 10.35992/pdm.mo2023.1829.

ACCESS TO EARLY CHILDHOOD EDUCATION IN THE STATE OF MATO GROSSO-BRAZIL: AT THE END OF THE NATIONAL EDUCATION PLAN (2014-2024)

Maria Cristiana da Silva Cadidé Vilela
Universidad Internacional Iberoamericana (Brazil)
maria.dasilva1@doctorado.unini.edu.mx - https://orcid.org/0000-0003-1861-8733
Carlos Tadeu Queiroz de Morais
Universidad Internacional Iberoamericana (Brazil)
ctqueiroz@gmail.com - https://orcid.org/0000-0001-8961-7450

Resumo. The objective of the study presented here is to present the access to the first stage of basic education, early childhood education, from 0 to 5 years of age in the State of Mato Grosso, Brazil. The contribution of the study is manifested by understanding the importance of the work carried out in the educational field by the right of the child. Childhood is the period in which the whole structure of an individual is strengthened, in all its dimensions. Opportunely, the relevance of the development of this research is to investigate: how is the access to Early Childhood Education in the State of Mato Grosso, being at the end of the National Education Plan? The research method was conducted through quantitative research, based on the School Census, Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (INEP) and Instituto Brasileiro de Geografia e Estatística (IBGE) in recent years (2010 to 2021). The analysis was of a basic nature, based on numerical and statistical data by means of tables, graphs and data description.

Palavras-chave: Access, care, children, Mato Grosso.

O ACESSO À EDUCAÇÃO INFANTIL NO ESTADO DE MATO GROSSO–BRASIL: AO FINAL DO PLANO NACIONAL DE EDUCAÇÃO (2014-2024)

Resumo. O estudo aqui apresentado tem como objetivo apresentar sobre o acesso à primeira etapa da Educação básica, Educação Infantil, de 0 a 5 anos no Estado de Mato Grosso, Brasil. A contribuição do estudo, se manifesta por entender sobre a importância do trabalho realizado no âmbito educacional por direito da criança. A infância é o período que se alicerça toda a estrutura de um indivíduo, em todas as dimensões. Oportunamente, a relevância do desenvolvimento desta pesquisa vem investigar sobre: como está o acesso à Educação Infantil no Estado de Mato Grosso, estando ao final do Plano Nacional de Educação? O método de pesquisa foi realizado através de pesquisa quantitativa, a partir do Censo escolar, Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (INEP) e Instituto Brasileiro de Geografia e Estatística (IBGE) dos últimos anos

(2010 a 2021). A análise ocorreu de natureza básica, a partir dos dados numéricos e estatísticos por meio de tabelas, gráficos e descrição dos dados.

Palavras-chave: Acesso, atendimento, criança, Mato Grosso.

ACCESO A LA EDUCACIÓN DE LA PRIMERA INFANCIA EN EL ESTADO DE MATO GROSSO–BRASIL: ÚLTIMO AÑO DEL PLAN NACIONAL DE EDUCACIÓN (2014-2024)

Resumen. El estudio que aquí se presenta tiene como objetivo exponer sobre el acceso a la primera etapa de la educación básica, la educación infantil, de 0 a 5 años en el estado de Mato Grosso, Brasil. La contribución del estudio se manifiesta en la comprensión de la importancia del trabajo realizado en el campo educativo por derecho del niño. La infancia es el período que fundamenta toda la estructura de un individuo, en todas las dimensiones. Oportunamente, la relevancia del desarrollo de esta investigación viene a indagar sobre: ¿cómo es el acceso a la Educación Infantil en el Estado de Mato Grosso, estando al final del Plan Nacional de Educación? El método de investigación se llevó a cabo a través de la investigación cuantitativa, a partir del Censo escolar, Instituto Nacional de Estudios e Investigaciones Educativas Anísio Teixeira (INEP) y el Instituto Brasileño de Geografía y Estadística (IBGE) de los últimos años (2010 a 2021). El análisis se produjo de carácter básico, a partir de los datos numéricos y estadísticos a través de tablas, gráficos y descripción de datos.

Palabras clave: Acceso, atención, niños, Mato Grosso.

Introduction

The objective of the study presented here is to present the access to the first stage of basic education, early childhood education, from 0 to 5 years of age in the State of Mato Grosso, Brazil. The contribution of the study is manifested by understanding the importance of the work carried out in the educational field by the right of the child. Childhood is the period in which the whole structure of an individual is strengthened, in all its dimensions. Opportunely, the relevance of the development of this research is to investigate: how is the access to Early Childhood Education in the State of Mato Grosso, being at the end of the National Education Plan?

Goal 1 of the National Education Plan sets the following target: to universalize, by 2016, pre-school education for children between 4 (four) and 5 (five) years of age and to expand the supply of pre-school education in schools so as to serve at least 50% (fifty percent) of children up to 3 (three) years of age by the end of the term of this PNE (2014-2024).

It justifies, the realization of this, on the vows offered for the development of the Childhood, since it is of universal right of the child.

Offering an environment in which the child can develop integrally, physically, psychologically, intellectually and also socially, is, therefore, a state duty. Children are entitled to rights, according to public documents and policies, where they are provided for without distinction or discrimination on the grounds of race, color, sex, language, religion, political or other opinion, national or social origin, or any other condition, whether their own or that of their family.

According to the LDBEN (1996), the purpose of early childhood education, also

known as the first stage of basic education, is integral development, that is, a concept that understands that education should guarantee the development of individuals in all its dimensions, and should be constituted as a collective project.

Therefore, it recommends an organization by age groups (art. 30), being called nursery school (0 to 3 years) and pre-school (4 and 5 years), in both of which the child will be accompanied and stimulated in its development.

According to Vilela (2021) "The space that childhood occupies in our history progresses, according to some studies, the history of childhood brings us many possibilities and reflections, in relation to the way we understand and also how we relate to children"

The culture of assistance to families, in search of manpower for the labor market, speaks louder than the right of the small citizen, often times the state tends to allocate inadequate spaces, thus hindering the adaptation and acceptance of the child.

It is not possible to accept that young children are cared for in inappropriate, inospospitable spaces that do not offer accessibility, that do not motivate the child, it is necessary to offer an adequate and attractive space, so that the exercise of their citizenship is fully realized.

It is well known that parents or guardians, often out of ignorance, enroll their children for other reasons, and not for the right that the child has under the law, therefore, where is the right instituted to the citizen of right?

Given the data collected, and the end of the decade of education (2014-2024) alerted to the need to raise awareness about access to young children in the state of Mato Grosso - Brazil. Data on access to early childhood education in the State of Mato Grosso - Brazil will be presented.

Methodology

The research method was conducted through quantitative research, based on the School Census, Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (INEP) and Instituto Brasileiro de Geografia e Estatística (IBGE) in recent years (2010 to 2021).

The analysis was of a basic nature, based on numerical and statistical data by means of tables, graphs and data description.

The organization took place essentially in view of the fact that it was a question of researching access to the first stage of Basic Education in the state of Mato Grosso, and initially a research was carried out on virtual official data. It was used from the reading of the data, analysis by means of the quantitative approach, with the objective of raising the statistical data, which covers the territory under study, based on André (2005), Marconi and Lakatos (2003), Gil (2009) and Bogdan and Biklen (1994, 2003).

Results

The State of Mato Grosso is located in the central western region of Brazil and is the only Brazilian state to have three of the country's main biomes: Amazon, Cerrado and

Pantanal. With geographical extension of 903,330 km², density = 3.9 inhabitants/km² and altitude = 322m.

Mato Grosso is a state of diverse peoples, a mixture of indigenous, black, Spanish and Portuguese peoples that portuguese that mixed in the early years of the colonial period. Cultural diversity is the main main characteristic of this people, it was these miscigenated people who received migrants, about 41% of the state's inhabitants were born in other parts of the country or abroad were born in other parts of the country or abroad.

In this way, the cultural diversity, provided overmaneira the reflection on spaces offered to the children, that more attend to the needs of the adult, from its organization, to the objectives of use of the space, sometimes asking to the parents or responsible, or why they use the playground or pre-school? - Many will respond : - "porque não tenho onde deixar", ou "porque precisa ser alguém na vida" ou até mesmo: "If I could I would not use it, I only use it because I need to work". Few emphasize that it is a "child's right".

Through the studies, the Maria Cecília Souto Vidigal Foundation[1] (FMCSV) recently presented that the main problems faced in frequenting the creche are: the lack of housing, or the lack of people who do not want it, or the lack of unity around their home.

According to the Basic Infrastructure Parameters for Early Childhood Education Institutions and based on the existing units/schools until 2016 and, in 100% of the units/schools, until 2023. The goals (2.1, 2.2, 2.3 and 2.6) of the Basic Infrastructure Parameters for Early Childhood Education Institutions, focusing on space and infrastructure, were established (BRAZIL, 2006):

- 2.1 only authorizes the construction and operation of public, private, philanthropic, confessional and community early childhood education units that meet the infrastructure requirements in accordance with the National Education National Directive and the State Education Council.
- 2.2 guarantee the construction and maintenance of units/schools/classrooms according to the expansion of the demand to be met and in accordance with the Basic Infrastructure Parameters for Early Childhood Education Institutions.
- 2.3 to maintain actions that increase accessibility in Early Childhood Education schools in relation to: architectural adequacy, accessible and adequate transportation supply according to current legislation [...] accessible technology resources.
- 2.6 provides for the maximum number of children per grouping/tour proportional to the size of the rooms, $1.^{50m2}$ per child in the age range from zero to five years old, considering only the free space.

After reflecting on the current situation and analyzing the goals, it is impossible not to comment on the legal and technical support when caring for small children without an adequate structure,

many times in crowded, inadequate spaces, in terms of accessibility that does not meet the expected demand, becoming a space that does not offer security and comfort for frequency and permanence.

The Pedagogical Policy for Early Childhood Education addresses in the document (2016) in the conception of the organization of spaces and environments the intentions and objectivity of educational practices. Therefore, planning and critical reflection on curricular life are necessary.

[1] Maria Cecília Souto Vidigal Foundation

It is necessary to expand the supply of early childhood education in creches in order to serve at least 50% (fifty percent) of children up to 3 (three) years of age until the end of the validity of this PNE (2014-2024).

Figure 1

Planned goals

Note. Fonte: IBGE -Adapted Author (2023).

Data from the 2018 report (Figure 1) show that the country has not yet met its targets. The State of Mato Grosso accounts for 15.9% of the expected access of 50%. In 2019, 1,591 schools offered early childhood education in the state of Mato Grosso, with 1,376 (86.5%) offering preschool and 775 (48.7%) offering kindergarten.

In 2021, 1,588 schools offered early childhood education in the state of Mato Grosso, with 1,377 (86.7%) offering preschool and 786 (49.5%) offering kindergarten. Over the last five years, it has been observed that the number of schools offering preschools has fallen while the number of schools offering kindergartens has increased. As shown in Table 1.

Over the last five years, the number of schools offering preschools has fallen by 0.8%, while the number of schools offering kindergartens has increased by 5.8%.

He noted the fact that, even with the obligation in art. 208, EC 59/2009, for students from 4 (four) years of age, the goals of the PNE (National Education Plan) are far from being achieved, noting that in the period of 2020 and 2021 there was impact of the pandemic COVID/19.

Table 1

Early Childhood Education Schools in the last 5 years (2017-2021)

	Schools in the last 5 years (2017-2021)					
ANO	**2017**	**2018**	**2019**	**2020**	**2021**	**%**
Total schools	1.581	1.578	1.591	1.597	1.588	-
Creche	743	772	775	768	786	**(+) 5,5%**
Preschool	1.388	1.370	1.376	1.382	1.377	**(-) 0,8%**

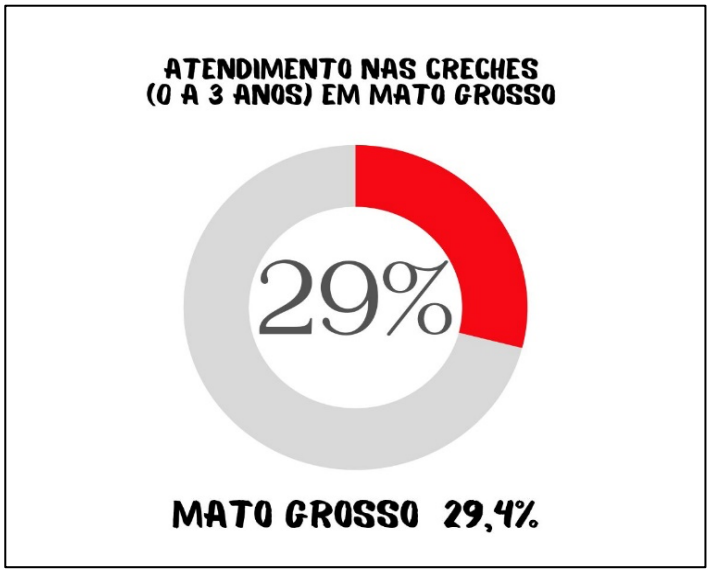
Note. Fonte: Instituto Nacional de Estudos Educacionais Anisio Teixeira. Adapted - Author (2023).

According to INEP - Brazil (2022) it is perceived that, despite the growth of enrollments in early childhood education until 2019 (it grew 5.5% from 2017 to 2019), there was a 7.3% drop between 2019 and 2021. This decrease occurred mainly due to the private network, which had a 17.8% reduction last year (15.8% drop in the nursery and 19.8% drop in the pre-school), while the public network had a 1.5% reduction (1.8% drop in the nursery and 1.3% drop in the pre-school).

In Mato Grosso in 2020 the percentage of access, or care, in the 0 to 3 years age group, according to figure 2, shows a low rate of 29.4% - below the national average of 35.6%.

Figure 2

Nursery care (0 to 3 years) in Mato Grosso

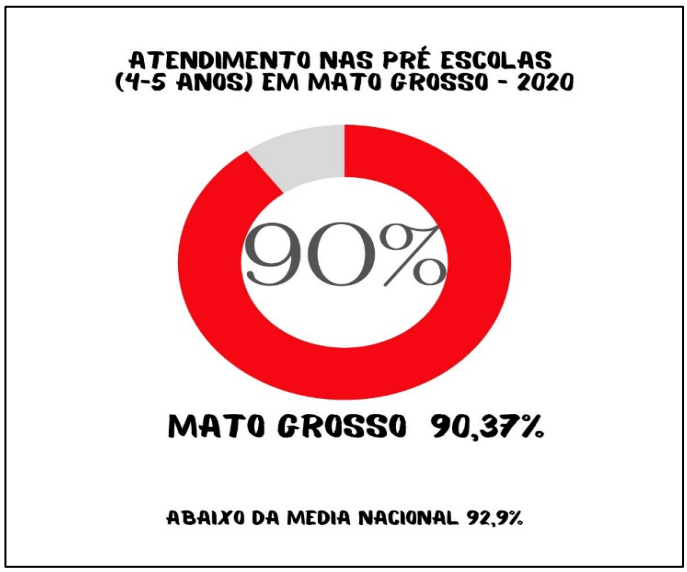


Note. Fonte : INEP | Organized by Datapedia.info. Adapted - Author (2022)

For the 4 to 5 year-old age group, according to Figure 3, it also shows that access or care is low at 90.37%, a low rate - below the national average of 92.9%.

Figure 3

Atendimento nas Pré-scolas (4 a 5 anos) em Mato Grosso

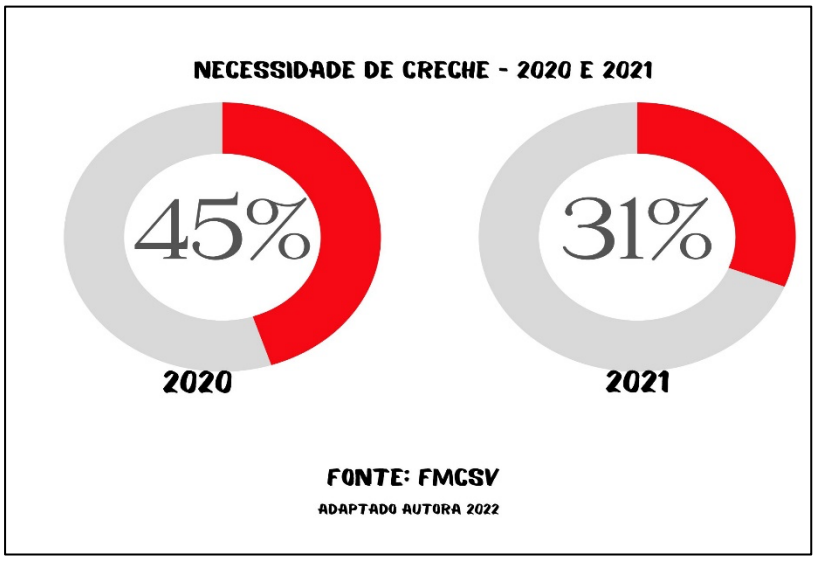


Note. Fonte : INEP | Organized by Datapedia.info. Adapted - Author (2022)

According to the data, there is still a lack of housing supply, demand is high, and many children are without access. According to the National Education Plan (201-2024), in 2016, according to the Constitutional Amendment (EC) 59, universal access for children up to 4 years of age should be achieved.

Figure 4

Necessity of Creches



In the year 2020, there was a need to offer vacancies, 44.7% of children from 0 to 3 years of age fit the criteria of the Child Need Index (INC), there was an expansion in the supply of vacancies, in the year 2021, there was an enrollment rate in Early Childhood Education of approximately 89% of the public network and 11% of the private network, reaching an INC of 31%. It is estimated that, according to the FMCS (2021) a total of 337,362

thousand children in the age group 0 to 6 years old.

Discussion and conclusion

Historically, the conceptions of childhood, children's rights and children's education have been changing as a result of the economic, political, social and cultural transformations that have taken place in society, and new public policies for children have been implemented.

Thus, every child, from birth, has had his or her right to education, health and food, guaranteed by the current Federal Constitution, by the Statute of Children and Adolescents and by the Law of National Education Guidelines and Bases, as well as by the current National Education Plan.

However, the Brazilian child population is neglected, especially the children of Mato Grosso, although much is written and spoken about quality, care and education, and the state's duty to the child population, including the population of Mato Grosso, yearns for public policies that make their rights as citizens viable.

Brazilian municipalities, guided by official directives, have been working to guarantee children's access to early childhood education and, in recent decades, have been working and developing public policies to meet the real demand; however, it is up to us researchers to investigate and present the discussions in order to better think, plan and develop policies for children and for children.

It is worth noting that studying the access of the child to early childhood education is a concern including access and quality of care, therefore, a doctoral research is being carried out by this author, where the problem is about the space of care, as the need to promote the rights of the small Brazilian citizen, with the objective of subsidizing and contributing to the development of public policies designed and instituted for education, specifically for early childhood education.

In this context, Rosemberg (2014) states that, although we already have some achievements, there is still much to advance when we reflect on public policies for Brazilian early childhood education. With this legal and political order, and aiming to overcome the poor-to-poor approach, the concern turned to guarantee the minimum conditions necessary for proposals and strategies that aim at quality, resulting in a series of official documents that, since 1993, the Ministry of Education (MEC) has tried to implement as a public policy of democratic and quality Early Childhood Education.

According to Lazaretti and Magalhães (2019) since then, the implementation of standards and guidelines has broadened the conceptions of early childhood education, children and infancy, achieving important advances in pedagogical practices. Some important conquests were achieved, but not enough, in the face of the political, economic and social environment, marked by inequality and lack of legal guarantees.

Agreeing with the goal: 4.2 of the SDG 2030 agenda of the United Nations (United Nations), to ensure that children in early childhood have access to quality development, require safe spaces with sustainable and natural elements that introduce them to life in cities and human settlements.

Making an analysis according to the data presented above, the state of Mato Grosso, when it comes to early childhood education, has a very low level, considered poor for the success of quality, access, and achievement of pre-established goals, making valid a scientific proposal for the improvement of care.

It is expected in this study to demonstrate the real needs, for the access of the children to the gross domestic product, so that it results in the accompaniment and better effectiveness in the attendance to the child as a citizen of right, attending to the development, emotional, physical and intellectual.

In addition to demonstrating the mandatory need for the supply of housing, the goals also reflect the well-being and comfort of the child, since this is a relevant concern, and we cannot lose sight of the safety, quality and training of the professionals who work there.

At the end of this study, it is expected to have presented data on access to early childhood education in the state of Mato Grosso in Brazil, subsidizing the institutions related to public policies for basic education, thus avoiding inadequate and unsatisfactory investments, remaining inadequate. It is necessary to implement the right of the child, guaranteeing criteria for integral development, with its own spaces, prepared for infancy.

References

André, M. (2005). Pesquisa em educação: questões de teoria e de método. *Educ. Technol. 10*(1), 29-35.

Gesqui, L. C. & Fernandes, A. G. (2021) Desafios na oferta de vagas em creches da rede pública municipal de ensino. *Jornal de Políticas Educacionais, 15*(5).

Gil, A.C. (2009). *How to develop research projects.* Atlas.

Lakatos, E.M. and Marconi, M.A. (2003). *Fundamentals of scientific methodology* (5th Ed.). Atlas.

Marconi, M.A. & Lakatos, E.M. (2007). Research Techniques. São Paulo: Atlas.

Rosemberg, F. (2014). Políticas Públicas e Qualidade da Educação Infantil. In Santos, M.O. dos S.; Ribeiro, M.I.S. (Orgs.). *Educação Infantil: os desafios estão postos e o que estamos fazendo?* Sooffset.

Vilela, M., & Morais, C. (2021). O Espaço Destinado a Educação Infantil e o Desenvolvimento: um Estudo Bibliográfico. In *Anais do XXIX Seminário de Educação*, (pp. 1240-1253). Porto Alegre: SBC.

Brazil. (1988). Constitution of the Federative Republic of Brazil of 1988. http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm.1988

Brazil. (1990). Law No. 8.069, of July 13, 1990. *Estatuto da Criança e do Adolescente*. http://www.planalto.gov.br/ccivil_03/leis/8069.htm.

Brazil. (2021). final yearbook. www.todospelaeducacao.org.br; https://todospelaeducacao.org.br/wordpress/wp-content/uploads/2021/07/Anuario_21final.pdf

Brazil. (2006) Emenda Constitucional, nº. 53. http://www.planalto.gov.br/ccivil_03/constituicao/Emendas/Emc/emc53.htm#art3

Brazil. (2009). Ministry of Education. Secretaria de Educação Básica. Teorias do espaço escolar. Brasília: University of Brasília. (Professional - Technical training course

for education officials). http://portal.mec.gov.br

Brazil. (2012) Ministério da Educação. Secretaria de Educação Básica. Diretrizes curriculares nacionais para a educação infantil / Secretaria de Educação Básica. - Brasília: MEC, SEB, 2010. http://portal.mec.gov.br/dmdocuments/diretrizescurriculares_2012.pdf

Brazil. (2018). National parameters of quality in early childhood education. Brasília: Undime. https://www2.senado.leg.br/bdsf/bitstream/handle/id/70320/65.pdf.

Brazil. Lei de Diretrizes e Bases da Educação Nacional. https://www2.senado.leg.br/bdsf/bitstream/handle/id/70320/65.pdf.

Fundação (2020), Maria Cecília Souto Vidigal Foundation. https://primeirainfanciaprimeiro.fmcsv.org.br/dados/estados

Lazaretti, L. M. & Magalhães G. M. (2019). Early childhood goes to school: in defense of developmental education for all children. *Obutchénie: Revista de Didatica e Psicologia Pedagógica, 3*(3), 1-21. https://doi.org/10.14393/OBv3n3.a2019-51702

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:

Campoverde Bustos, F. M., Nieto Cárdenas, X., & Takeuchi, C. P. (2023). Análisis de ladrillos ecológicos fabricados con suelo limo-arenoso, cemento, viruta y papel, en base a resistencia, costo y deformación. *Project, Design and Management,* número monográfico, 37-56 . 10.35992/pdm.mo2023.1842.

ANALYSIS OF ECOLOGICAL BRICKS MADE OF SILTY-SANDY SOIL, CEMENT, WOOD CHIPS AND PAPER, BASED ON STRENGTH, COST AND DEFORMATION

Franklin Mauricio Campoverde Bustos
Catholic University of Cuenca (Ecuador)
franklinc156@gmail.com -
Xavier Nieto Cardenas
National University of Colombia (Colombia)
jnietoc@unal.edu.co
Caori Patricia Takeuchi
National University of Colombia (Colombia)
cptakeuchit@unal.edu.co

Summary. Brick manufacturing involves firing clay at high temperatures, generating excessive consumption of energy and resources. Therefore, the need to replace the traditional brick with an ecological brick was born. The objective of this research is to manufacture an ecological brick using cement, silty-sandy soil, wood chips and bond paper, seeking to provide beneficial properties. The soil was first graded and stabilized with Portland cement. To prevent the chips and bond paper from absorbing the mixing water used, they were placed in saturation for 48 hours. The idea was to use a first dosage with half the volume with paper, shavings or both, and then a second and third dosage with a variation of +/- 10%, respectively. In order to perform the necessary tests, NTE INEN 3066 establishes the requirements and test methods. The results show that an ecological brick with 40% of chips resists 39 kgf/cm2 (28%) more than a traditional one, while an ecological brick with 50% of chips resists 31 kgf/cm2 (22%) more than a traditional one, in addition, the traditional brick is more economical, however, its elaboration is due to an industrialized process which minimizes its cost compared to an ecological brick. The ability of the ecological brick to deform and continue to receive load, unlike a traditional brick that reaches its maximum resistance without major deformation, is important because it would allow a building to have a more elastic behavior.

Key words: Compression, deformation, dosages, silty soil, wood chips.

ANÁLISIS DE LADRILLOS ECOLÓGICOS FABRICADOS CON SUELO LIMO-ARENOSO, CEMENTO, VIRUTA Y PAPEL, EN BASE A RESISTENCIA, COSTO Y DEFORMACIÓN

Franklin Mauricio Campoverde Bustos
Universidad Católica de Cuenca (Ecuador)
franklinc156@gmail.com ·
Xavier Nieto Cárdenas
Universidad Nacional de Colombia (Colombia)
jnietoc@unal.edu.co
Caori Patricia Takeuchi
Universidad Nacional de Colombia (Colombia)
cptakeuchit@unal.edu.co

Resumen. El ladrillo involucra en su fabricación la cocción de arcilla a grandes temperaturas, generando un consumo excesivo de energía y recursos. Por ello nace la necesidad de sustituir el ladrillo tradicional por un ladrillo ecológico. El objetivo de esta investigación es fabricar un ladrillo ecológico utilizando cemento, suelo limo-arenoso, viruta de madera y papel bond, buscando que aporten propiedades beneficiosas. Primero se clasificó y estabilizó el suelo con cemento Portland. Para evitar que la viruta y el papel bond absorban el agua de mezclado utilizada, se colocaron en saturación durante 48 horas. Se partió de la idea de utilizar una primera dosificación con la mitad del volumen con papel, viruta o ambos, para luego hacer una segunda y tercera dosificación con una variación de +/- 10%, respectivamente. Para realizar los ensayos necesarios, la normativa NTE INEN 3066 establece los requisitos y métodos de ensayo. Los resultados muestran que Un ladrillo ecológico con 40% de viruta resiste 39 kgf/cm2 (28%) más que un tradicional, mientras que un ladrillo ecológico con 50% de viruta resiste 31 kgf/cm2 (22%) más que un tradicional, además, el ladrillo tradicional es más económico, sin embargo, su elaboración se debe a un proceso industrializado lo que minimiza su costo frente a un ladrillo ecológico. La capacidad del ladrillo ecológico de deformarse y seguir recibiendo carga a diferencia de un ladrillo tradicional que alcanza su resistencia máxima sin mayor deformación, es importante pues le permitiría a una edificación tener un comportamiento más elástico.

Palabras clave: Compresión, deformación, dosificaciones, suelo limoso, viruta de madera.

Introduction

The construction of buildings and housing is a fundamental aspect nowadays due to the significant demographic and population growth, which causes an increase in the demand for construction materials, which is why it is important to look for alternative materials to replace the traditional ones, reduce costs, provide safety and reduce the negative environmental impact, since several studies have shown that the environmental situation is precarious, several human activities and especially the procurement and manufacture of construction materials produce a negative environmental impact due to various factors.

Wood shavings and paper are common and abundant wastes in our environment, wood shavings are a waste obtained in sawmills, paper is found as a waste in educational establishments, companies, bookstores, etc., and we are looking for ways to recycle these materials to give them a new use, helping to reduce the negative environmental impact that is generated when they are discarded. These materials have a common characteristic, which is their light weight, so including them in elements such as bricks would reduce their weight,

which would produce constructive and economic benefits. Another characteristic of wood chips and paper is their elasticity, which would help a brick to have a large deformation instead of "exploding" abruptly as a normal brick would when subjected to a large load. As the chips and bond paper are materials that become waste after fulfilling their function, the feasibility of this study is very broad since it does not demand high manufacturing costs, in addition to the fact that its production does not involve a large amount of energy as would a normal brick that is baked in ovens at high temperatures, generating considerable CO2 emissions.

The great importance of cement today is evidenced by the fact that it is the most produced material in the world with about 4070 million tons per year according to the latest statistics provided by Index Mundi in 2013 in its Hydraulic Cement report: World Production, By Country. The growth in cement consumption is directly related to the increase in the world population and to the development of countries, since this involves civil engineering works, infrastructure, etc., according to different studies, concrete and mortar will continue to be the cheapest means of construction, at least in the short term, and their consumption will continue to increase in proportion to population growth and development. For these reasons, this study seeks to use cement as a material in the manufacture of ecological bricks.

In our environment there is still not enough research on new construction materials to replace traditional materials partially or completely, the lack of interest in the care of the environment by most professionals and contractors causes that not enough importance is given to the search for new materials. Speaking of bricks specifically, such lack of interest in the environment generates ecological damage at the time of construction, as bricks are one of the most demanded materials in the country and in America in general, and taking into account that their manufacture generates considerable CO2 emissions, more research should be carried out on new ecological materials to replace traditional ones, in addition to providing beneficial properties in terms of resistance and economy.

A construction material widely used for masonry is brick, which involves in its manufacture the firing of clay at high temperatures, which produces an excessive consumption of energy and unrecoverable resources, in addition to the generation of soot and carbon monoxide. Due to these circumstances, the need arises to find a way to replace the traditional brick with an ecological brick that involves in its manufacture recycled materials that are common in our environment and also eliminates certain processes that do not generate an excessive consumption of resources, since they are generally unrecoverable.

Wood shavings and paper are common and abundant wastes in our environment, wood shavings are a waste obtained in sawmills, paper is found as a waste in educational establishments, companies, bookstores, etc., and we are looking for ways to recycle these materials to give them a new use, helping to reduce the negative environmental impact that is generated when they are discarded. These materials have a common characteristic, which is their light weight, so including them in elements such as bricks would reduce their weight, which would produce constructive and economic benefits.

Materials

It has been demonstrated that stabilized soil has a superior durability and technical quality compared to adobe or simple rammed earth. The emergence of compressed earth block production technology, in European, African and Latin American countries, and its application in construction since the 1950s, has continued scientific progress and experimentation, as well as its technical merits, as stated by CRA Terre (as cited in Gatani 2000). An abundant body of knowledge has been developed by research centers, industrialists, entrepreneurs and builders, making this technology an alternative to other technologies of today.

Begliardo, Sanchez, Panigatti, Casenave and Fornero (2006) state that cement-treated soil can be made with:

- Clean granular soil.
- Mixture of granular and fine soils, predominantly silty.
- Mixture of granular and fine soils, predominantly clayey.
- Loamy soils.
- Clay soils.

However, the soil suitable for making soil-cement bricks is sandy in nature, with a proportion of fines that gives it low plasticity for block molding (Roseto 2006).

The Instituto Ecuatoriano de Normalización INEN establishes the norms to carry out the necessary tests to determine the soil plasticity index.

- Granulometric analysis of soil (NTE INEN 696)

The granulometric analysis consists of separating a sample into several fractions, Coyasamín (2016) states that the sample is separated according to its size by sieving the material using a series of meshes or sieves that are specified in the Ecuadorian Technical Standard INEN 154, with their measurements determined as shown in Table 1. Ecuadorian Technical Standard INEN 696 (2011) states: This test method is mainly used to determine the graduation of materials (...). The results are used to determine the compliance of particle size distribution with the requirements of the applicable specifications and to provide information necessary for the control of the production of various aggregate products and aggregate-containing mixtures. (p.1)

- Determination of the liquid limit of soils (NTE INEN 691)

The Ecuadorian Institute of Normalization in its Standard NTE INEN 691 (1982) defines the liquid limit as: "A test method consisting of determining the water content of a soil, (...) using a mechanical device (Casagrande Cup) in which, with a certain number of blows, the creep of the soil is established under standardized conditions." (p.1). In addition, it establishes that this test should be done only with the fraction of soil that passes the 425 μm sieve (No. 40).

- Determination of soil plasticity limit (NTE INEN 692)

The Ecuadorian Institute of Normalization in its Standard NTE INEN 692 (1982) defines the plastic limit as follows: "This test method consists of determining the water content of a soil at the boundary between its plastic and solid behavior, for which the rolling process is used to gradually evaporate the water that begins to crack or disintegrate." (p.1). As in the liquid limit, it is specified that this test should be done only with the fraction of soil that passes the 425 μm sieve (No. 40).

After the tests, it is necessary to define the type of soil according to its characteristics as mentioned by Bañón and Beviá (2000) based on the classification given by the American Association of State Highway and Transportation Official- AASHTO (2009).

For the determination of the group index and soil classification, the one given by the American Association of State Highway and Transportation Official- AASHTO (2009) is used. It considers seven basic groups of soils, numbered from A-1 to A-7, and some of them have subdivisions; A-1 and A-7 have two subgroups while A-2 has four, as mentioned by Bañón and Beviá (2000). It is also stated that, if it is desired to determine the relative position of the soil within the group, it is necessary to determine the group index (GI) as expressed in equation [1],

which is expressed as an integer value between 0 and 20, as a function of the percentage of soil passing through the #200 ASTM sieve. (Bañón and Beviá, 2000).

$$IG=(F\_200-35)\ [0.2+0.005(LL-40)]+0.01(F\_200-15)\ (IP-10)\ [1]$$

Where:

F200 is the percentage of soil passing the #200 sieve, expressed as a whole number.

LL is the liquid limit of the soil, expressed as an integer.

IP is the soil plasticity index, expressed as an integer.

Cadena (2013) defines Portland cement as a hydraulic cement that is composed mainly of hydraulic calcium silicates, which set and harden when a chemical reaction occurs with water, called hydration. During this reaction, cement combines with water to form a paste which, when sand is added, is called mortar. The ASTM C 150 standard defines different types of cement, according to the uses and needs of the construction market:

Type I.- This type of cement is for general use, and is used when special properties and characteristics are not required. Among the uses where this type of cement is used are: floors, pavements, buildings, structures, prefabricated elements. (Coyasamin, 2016, p11)

Type II - Portland cement type II is used when protection against moderate sulfate attack is required, such as in drainage pipes. In cases where maximum limits are specified for the heat of hydration, it can be used in large volume works and particularly in hot climates, in applications such as retaining walls, piles, dams, etc. (Coyasamín, 2016, p12)

Type III: This type of cement develops high strengths at early ages, at 3 and 7 days. This property is obtained by grinding the cement more finely during the grinding process. Its use is due to specific construction needs, as in the case of roads and highways. (Coyasamin, 2016, p12)

Type IV - Portland cement type IV is used when, due to the needs of the work, the heat generated by hydration must be kept to a minimum. The uses and applications of type IV cement are directed to works with massive structures, such as large dams. (Coyasamin, 2016, p12)

Hydraulic blended cements have been developed because of two fundamental aspects: first, the industry's interest in energy conservation and second, the economics of their production.

To stabilize the soil this study applied Portland cement, which is a hydraulic cement that is composed mainly of hydraulic calcium silicates, which set and harden when a chemical reaction with water occurs, called hydration (Cadena, 2013).

Regarding the process that water goes through with cement, Del Campo (1963) states that, when cement is kneaded with a certain amount of water, a plastic, moldable mass is formed, which little by little, as time goes by, loses its plasticity, and the wet appearance it had at the beginning disappears. "Technologically, it is said that the paste is setting, the process continues, and there comes a moment when it stops being plastic and becomes a rigid body. When this change in its structure occurs, it is also said that the setting period has ended and the hardening period has begun." (p.38)

Wood shavings and paper are common and abundant wastes in our environment, wood shavings are a waste obtained in sawmills, paper is found as a waste in educational establishments, companies, bookstores, etc., and we are looking for ways to recycle these materials to give them a new use, helping to reduce the negative environmental impact that is

generated when they are discarded. These materials have a common characteristic, which is their light weight, so including them in elements such as bricks would reduce their weight, which would produce constructive and economic benefits. Another characteristic of wood chips and paper is their elasticity, which would help a brick to have a large deformation instead of "exploding" abruptly as a normal brick would when subjected to a large load.

Absorption test

To carry out the necessary tests, the Ecuadorian Institute of Standardization in its standard NTE INEN 3066 establishes the requirements and test methods for concrete blocks, this standard was chosen because of the use of cement in the manufacture of ecological bricks. Annex D of the Ecuadorian Technical Standard NTE INEN 3066 defines the following procedure for the absorption test:

"Immerse the test units in water at a temperature between 16 °C and 27 °C for a period of 24 hours to 28 hours." (Instituto Ecuatoriano de Normalización, 2016)

"Determine, then, the mass of the completely submerged units, while suspended a wire, and record this value as Mi (mass of the submerged sample)." (Instituto Ecuatoriano de Normalización, 2016)

"Remove them from the water and allow them to drain for 60 seconds ± 5 seconds on a wire mesh, remove the visible water from the surface with a damp cloth, determine their mass and record this value. Repeat this procedure every 24 hours until the difference in mass between two consecutive weighings is less than 0.2%. Record this result as Ms (mass of the saturated sample)." (Instituto Ecuatoriano de Normalización, 2016)

"Dry them in a ventilated oven, between 100 °C and 115 °C. Weigh the units every 24 hours until the difference in mass between two consecutive weighings is less than 0.2 %. Record this result as Md (oven-dried sample masses)." (Instituto Ecuatoriano de Normalización, 2016)

Once the procedure described above has been carried out, the Ecuadorian Institute of Normalization has established the following equations for the calculations:

$$Absorción, (kg/m^3) = \frac{M_s - M_d}{M_s - M_i} \times 1000 \qquad [2]$$

Where:

Ms is the mass of the saturated unit (kg),

Mi is the mass of the submerged unit (kg),

Md is the mass of the oven-dried unit (kg).

Compression test

The parameters for the preparation of the samples to be tested can be found in Annex E of Ecuadorian Technical Standard 3066, which states that: After delivery to the laboratory, store the units (...) at a temperature of 24 °C ± 8 °C and a relative humidity of less than 80 % for at least 48 hours. However, if faster compression results are needed, store the units (...), with a stream of air from an electric fan passing through them, for a period of at least 4 hours. The oven should not be used to dry these units. (p19)

It also establishes the formula for determining the compressive strength:

$$Resistencia\ a\ la\ compresión = \frac{P_{máx}}{A_n} \qquad [3]$$

Where

- Pmax. = maximum compressive load, (kgf)
- An = net area of the unit (cm2)

Method

Soil identification and classification

The natural soil was obtained from the Borma sector of the Déleg canton in the province of Cañar, using UTM coordinates as reference: 728813.73 E; 9687510 S; Zone 17M. We worked with material that passes the N°4 sieve and it was observed that it is a silty soil, so to reduce its plasticity we chose to add sand, having a soil: sand ratio of 1:1. Once these conditions were established, the following tests were carried out to classify the material.

According to the procedure established in the Ecuadorian Technical Standard INEN 691, the liquid limit of the natural soil is calculated and then the liquid limit of the soil added with sand, as shown in Table 1 and Table 2, respectively.

Table 1
Natural soil water content

# of jar	# of strokes	Wet weight + Jar (g)	Dry weight + Jar (g)	Jar Weight (g)	water content
16	**43**	28.64	25.62	17.57	27.28
15	**30**	27.66	24.83	17.81	28.73
9	**21**	28.24	24.92	17.07	29.72
6	**13**	28.36	24.82	16.96	31.05

Table 2
Soil water content plus sand

# of jar	# of strokes	Wet weight + Jar (g)	Dry weight + Jar (g)	Jar Weight (g)	water content
15	**40**	29.9	27.45	17.81	20.26
22	**32**	29.25	26.85	17.69	20.76
31	**23**	31.87	28.84	17.89	21.67
6	**13**	30.22	27.14	16.96	23.23

Results:

- Liquid limit of natural soil = 29%
- Liquid limit of sand = Non-plastic
- Soil liquid limit + sand = 21%

According to the procedure established in the Ecuadorian Technical Standard INEN 692, the plastic limit of the natural soil is calculated and then the plastic limit of the soil added with sand, as shown in Table 3 and Table 4, respectively. Additionally, applying INEN 692, the plasticity index of the materials is calculated.

Table 3
Plastic limit of natural soil

# of jar	Wet Weight +Tartar (g)	Dry Weight +Tartar (g)	Jar Weight (g)	water content	Average water content (%)
27	8.38	7.99	6.05	16.74	**17.0**
24	9.01	8.54	6.21	16.79	
4	11.39	10.93	8.72	17.23	
34	9.24	8.71	6.21	17.49	

Table 4
Plastic limit of soil plus sand

# of jar	Wet Weight +Tartar (g)	Dry Weight +Tartar (g)	Jar Weight (g)	water content	Average water content (%)
27	8.25	7.87	6.05	17.27	**17.2**
24	8.47	8.09	6.21	16.81	
4	11.64	11.13	8.72	17.47	
34	8.99	8.51	6.21	17.27	

- Natural soil plasticity index = 29% - 17% = 12%
- Soil plasticity index + sand = 21% - 17.2% = 3.8%

Subsequently, the particle size is determined (Table 5).

Table 5

Soil granulometry plus sand

Sieve No	Diameter (mm)	Retained weight	% retained	% passing
4		0.00	0.00	100.00
10	2	20.09	5.41	94.59
40	0.425	149.12	40.13	50.46
100		156.28	42.06	16.40
200	0.075	43.20	11.63	0.77

With the results obtained from the above tests, the material is classified as shown in Table 6. Based on the classification obtained, the beneficial use of using soil plus sand in the study is confirmed. Once the desirable characteristics have been found, the remaining materials for dosing are prepared.

Table 6

AASHTO material classification

Sample	Group	Type of materials characteristics	Rating
Natural soil	A-2-6 (0)	Gravels and silty and clayeysands	Regular
Soil+ Sand	A-1-b (0)	Gravel fragments, stone and sand	Excellent to good

Chip sampling and preparation

The chips chosen are medium and fine, discarding coarse chips because their dimensions could generate porosities in the bricks. The wood chips come from two types of wood, oak and eucalyptus. To prevent the chips from absorbing too much of the mixing water used, they were left in saturation for 48 hours as shown in Figure 1, and it was decided to cover them to prevent evaporation and thus conserve moisture.

Figure 1
Chip and paper in the process of saturation

Sampling and preparation of bond paper

Bond paper can be found in public and private institutions as waste, because after fulfilling its function it is considered garbage. For this study, bond paper was obtained and recycled from the Universidad Católica de Cuenca, Azogues.

75gr. bond paper was chosen because it is the most widely used in the field. To prevent the paper from absorbing the mixing water used, it was left in saturation for 48 hours as shown in Figure 2.

Figure 2
Paper in the process of saturation

Using a Hobart mixer, the 75 g bond paper was homogenized by shredding it and adding water until a uniform consistency was achieved, as shown in Figure 3.

Figure 3
Bond paper homogenization

Brick manufacturing

The dimensions of the molds were chosen according to the traditional bricks existing in the market, thus having already established dimensions of 12cm x 24cm x 8cm.

The fine aggregates (cement and soil plus sand) are mixed in the proportions foreseen according to the dosage chosen, until they are correctly homogenized, as shown in Figure 4. The paper, chips or both, as the case may be, are added to this mixture and mixed and homogenized again until an appropriate workability is obtained. If necessary, water is added to the mixture to improve its workability and to obtain an optimum mixture for working, as shown in Figure 5.

Figure 4
Dry blending of cement, soil and sand

Figure 5
Homogenization of all materials

Consequently, the mixture is placed in wooden molds and then beaten with a rubber hammer to get the material to settle properly and eliminate excess air. After ensuring the correct distribution of the material and covering empty spaces, the mold is removed, leaving the ecological bricks as shown in Figure 6, which also shows the presence of a metal plate used to level the upper face that will receive the load in the compression tests.

Figure 6
Demolded bricks with presence of leveling plate

Dosages

For this research, we worked with a soil-cement volume ratio of 1:1.5 because we are looking for the "ecological mortar" to have a good percentage of cement to increase resistance.

Mixes are started with 50% of the volume of a brick with paper, chips or both, as the case may be. With this starting point, it was considered to make dosages containing 60% and another with 40% of the mentioned materials, i.e., the idea was to use a first dosage with half of the volume with paper, chips or both, and then make a second and third dosage with a variation of +/- 10%, respectively. Table 7 shows the volumes of each material used in the dosages.

Table 7
Volumes of material required to manufacture one unit of ecological bricks

Material	40% V (cm^3)	50% V (cm^3)	60% V (cm^3)	40% P (cm^3)	50% P (cm^3)	60% P (cm^3)	40% P+V (cm^3)	50% P+V (cm^3)	60% P+V (cm^3)
Cement	1656	1380	1104	1656	1380	1104	1656	1380	1104
Soil plus sand	1104	920	736	1104	920	736	1104	920	736
Paper	----	----	----	1840	2300	2760	920	1150	1380
Chip	1840	2300	2760	----	----	----	920	1150	1380

Absorption and compression tests

The Ecuadorian Technical Standard NTE INEN 3066 establishes the parameters to carry out absorption and compression tests on concrete blocks, applying the following equations. Once the procedure described above (Figure 7) has been carried out, the Ecuadorian Institute of Standardization has established the following equations for the calculations:

$$Absorción, (\%) = \frac{M_s - M_d}{M_d} \times 100 \qquad [4]$$

Where:

Ms is the mass of the saturated unit (kg),

Md is the mass of the oven-dried unit (kg).

It also establishes the formula for determining the compressive strength:

$$Resistencia\ a\ lacompresión = \frac{P_{máx}}{A_n} \qquad [5]$$

Where

Pmax. = maximum compressive load, (kgf)

An = net area of the unit (cm^2)

Figure 7
Compression test of an ecological brick with chips

Results

Compressive strength and deformation

Once the compression tests were carried out, it was observed that the strength of the ecological bricks containing paper in their dosage was below the strength of traditional bricks. It is also observed that the ecological bricks with 40% and 50% chip content exceed the stress resisted by traditional bricks by 28% and 22% respectively, the effect of curing on the bricks does not vary more than 10kg/cm2, so the effect is not taken into account. The following stress-strain plots show the behavior of traditional brick vs. Ecological bricks.

Figure 8
Effort vs. Deformation, traditional brick and chip bricks

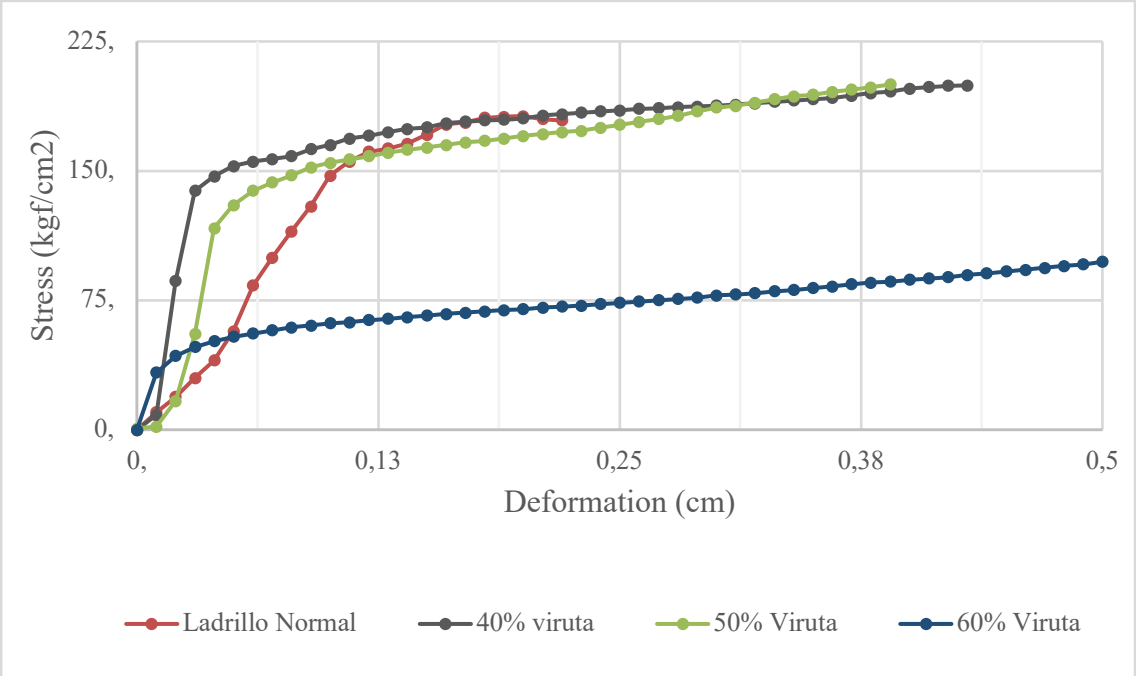


Figure 9
Effort vs. Deformation, traditional brick and paper bricks

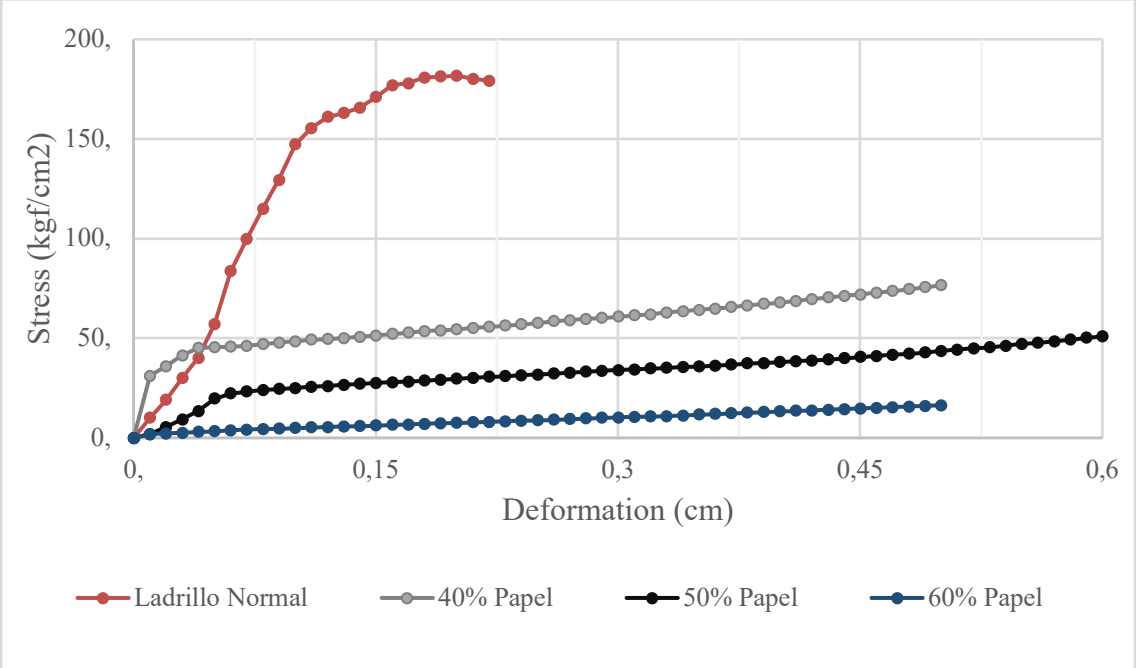
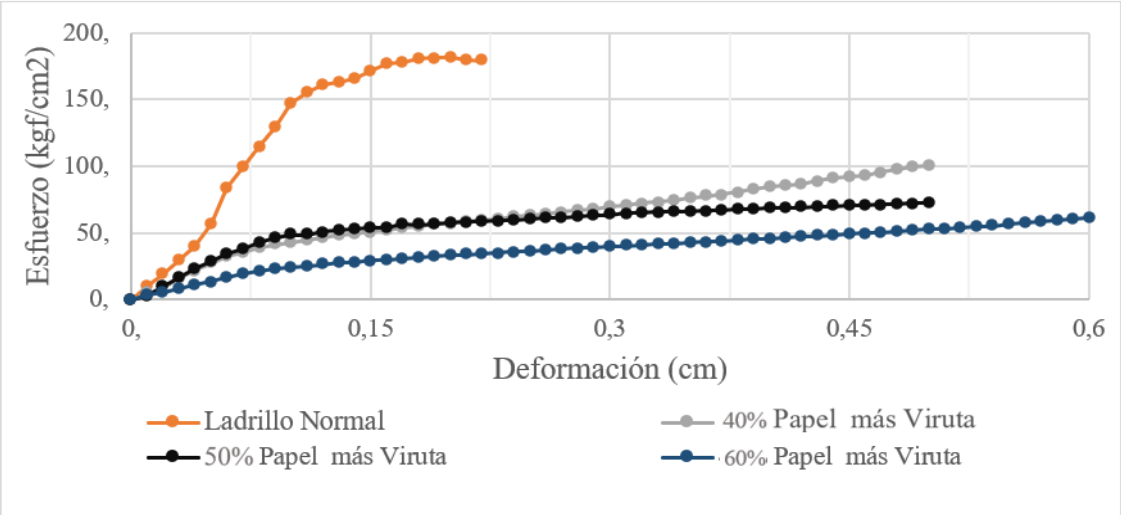


Figure 10

Effort vs. Deformation, traditional brick and bricks with chips plus paper



The graphs in Figures 8, 9 and 10 show that the ecological bricks have the capacity to continue receiving load and continue deforming, unlike traditional bricks that reach their ultimate stress and stop resisting load, i.e., traditional bricks show brittle failure, while ecological bricks show ductile failure. In addition, from a seismic point of view, a lighter building generates lower lateral inertial forces. In the same way, the failure presented by the ecological bricks would allow people not to be affected by falling walls during an earthquake, due to their deformation, without brittle failure (Figure 11).

Figure 11

Masonry failure at the Millennium School - Pedernales Ecuador

Note. Prepared by Eng. Xavier Nieto Cárdenas

Compressive strength and deformation

The weight obtained shows an advantage of ecological bricks as they are lighter than traditional bricks, as shown in Table 8 below. This difference in weight compared to traditional bricks is approximately 1 kilogram. This difference can be magnified when analyzing the weight of a wall made with fired clay bricks; therefore, if the weight is greater, the supporting structure must be more resistant, which will increase its cost.

Table 8
Weight of bricks tested

Description	Weight
Traditional Brick	4.13 kg
Brick with 40% chips	3.46 kg
Brick with 50% chips	3.30 kg
Brick with 60% chips	2.70 kg
Brick with 40% Paper	3.15 kg
Brick with 50% paper	2.44 kg
Brick with 60% paper	1.88 kg
Brick with 40% chips plus paper	2.98 kg
Brick with 50% chips plus paper	2.94 kg
Brick with 60% chips plus paper	2.48 kg

Cost comparison

Since bricks with 40% and 50% of chips achieve the same strength as traditional bricks, a cost analysis of these elements alone was carried out. For the analysis of tables 9 and 10, only the value of the materials used was considered, leaving aside the production processes, since a traditional brick is produced in large-scale factories, while this research on ecological bricks, being innovative, is based on unit production.

Table 9
Cost of manufacturing a brick with 40% of chips

MATERIALS				
DESCRIPTION	**UNIT**	**QUANTITY**	**P. UNIT**	**COST**
Portland Cement	kg	3.98	0.15	0.597
Clean sand	m3	0.000552	10.25	0.006
Natural soil	m3	0.000552	0.1	0.0001
Wood chips	m3	0.001840	1.00	0.001
TOTAL				0.60

Table 10
Cost of manufacturing a brick with 50% of chips

MATERIALS				
DESCRIPTION	**UNIT**	**QUANTITY**	**P. UNIT**	**COST**
Portland Cement	kg	3.31	0.15	0.496
Clean sand	m3	0.000460	10.25	0.005
Natural soil	m3	0.000460	0.00	0.0001
Wood chips	m3	0.002300	1.00	0.001
TOTAL				0.50

Discussion and conclusions

Once the results of the study have been obtained, the following conclusions can be drawn:

The proposed dosages resulted in different values after the simple compression test, being evident a higher resistance for the dosages that contain a greater amount of cement, it is also observed that the wood chips provide lightness to the brick and optimum resistance, while the paper, although it manages to significantly reduce the weight, reduces the resistance of the brick. The dosages that reach and exceed the resistance of a traditional brick are those containing 40% and 50% wood chips.

In dosages with 36% cement, 24% soil plus sand and 40% chips or paper, the production cost, handling only values of materials, would be 60 cents or in other words 71% more than a traditional brick, while in dosages with 30% cement, 20% soil plus sand and 50% chips or paper, the production cost, handling only values of materials, would be 50 cents or what is equal to 43% more than a traditional brick.

The cost of an ecological brick is higher, but other factors must be taken into account, such as weight, since being approximately 1 kg lighter means that the base structure will have to support less weight, which would reduce construction costs.

An ecological brick with 40% chips resists 39 kgf/cm2 (28%) more than a traditional brick, while an ecological brick with 50% chips resists 31 kgf/cm2 (22%) more than a traditional brick. The strength of the other dosages is below the strength of a traditional brick, but could be compared to the strength of a class B concrete block.

An important factor is the ability of the ecological brick to deform and continue to receive load, unlike a traditional brick that reaches its maximum resistance without major deformation. This capacity is important because it would allow a building to have a more elastic behavior.

In the ecological aspect, the bricks of this research have several advantages over traditional bricks, starting with the fact that they do not require firing kilns, which means that they do not generate large CO and soot emissions, thus reducing the negative environmental impact.

Another important factor is the material used, because by recycling a common material such as wood chips, we contribute in an excellent way to the care of the environment.

The following recommendations can also be established:

Regarding the process of this research, the plasticity index of the natural soil must be taken into account and try to reduce it if necessary, since it is essential to achieve an appropriate mixture with the cement and achieve the required strength.

It is important to use molds with smooth surfaces that ensure a good finish of the brick, this is important at the time of the simple compression test because the load will be distributed uniformly. Finally, the curing time of 28 days of curing must be respected.

Continue with the research of ecological materials that can replace the traditional ones, and go deeper into the economic aspect of bricks with a percentage of chips, considering other important factors at the time of construction.

Compare with other elements such as pumice and concrete blocks, and vary the dimensions of the elements used in this research.

References

Bañón , L., & Beviá, J. F. (2000). *Road Manual. Volume II: construction and maintenance* (Vol. 2). Ortiz e Hijos, Contratista de Obras, S.A. http://hdl.handle.net/10045/1787

Barrientos, M., & Soria, C. (2013). Index Mundi. https://www.indexmundi.com/

Begliardo, H., Sánchez, M., Panigatti, M. C., Casenave, S., & Fornero, G. (2006). Soil-cement bricks made from surface soils and excavation muds for piles. Lecture. *Recycling of construction and demolition waste (CDW) and process waste (PR)PROCQMA.*

Cadena, G. (2013). *improvement of the mechanical properties of pozzolanic concretes to increase their resistance to sulfate attack.* Autonomous University of Queretaro. http://ri-ng.uaq.mx/handle/123456789/364

Coyasamin, O. (2016). *Comparative analysis of the compressive strength of traditional concrete, with concrete added with rice husk ash (RCA) and concrete added with sugar cane bagasse ash (SCBA).* [Undergraduate thesis]. Technical University of Ambato. http://repositorio.uta.edu.ec/jspui/handle/123456789/23482

Das, B. M. (1995). *Fundamentals of geotechnical engineering.* Thompson Learning.

Del Campo, M. (1963). The determination of the mixing water in set mortars and concretes. *Building Materials, 13*(111), 36-45. https://doi.org/10.3989/mc.1963.v13.i111.1798

Gatani, M. (2000). Soil-cement bricks: Traditional masonry based on a sustainable material. *Construction Reports, 51*(466), 35-47. https://doi.org/10.3989/ic.2000.v51.i466.713

Ecuadorian Institute of Standardization. (1982). *Ecuadorian Technical Standard NTE INEN 691: Soil mechanics. Determination of the liquid limit.* Official Publication.

Ecuadorian Institute of Standardization. (1982). *Ecuadorian Technical Standard NTE INEN 692: Soil mechanics. Determination of the plastic limit.* Official Publication.

Ecuadorian Institute of Standardization. (2011). Ecuadorian Technical Standard NTE INEN 154. Test sieves. Nominal dimensions of openings. Official Publication.

Ecuadorian Institute of Standardization. (2011). Ecuadorian Technical Standard NTE INEN 696: Aggregates. Granulometric analysis of fine and coarse aggregates. Official Publication.

Ecuadorian Institute of Standardization. (2016). *Ecuadorian Technical Standard NTE INEN 3066. Concrete blocks. Requirements and test methods.* Official Publication.

National Roads Institute. (2007). *Standard INV. E 102. Description and identification of soils (visual and manual procedure).* Official Publication.

Piedra, B. (2014). *Study to analyze the soil-cement or ecological brick in Cuenca* [Undergraduate thesis]. University of Azuay, Cuenca, Ecuador. http://dspace.uazuay.edu.ec/handle/datos/3638

Roseto, O. (2006). Blocks with Hypercompressed Soil-Cement Mixtures. *Cement Magazine*, *7*, 11-13.

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management
ISSN: 2683-1597

How to cite this article:

Polo Friz, E. G. (2023). Geotecnia y Arquitectura. Consideraciones sobre el paradigma actual en geotecnia y sus posibles desarrollos futuros. *Project, Design and Management, Monográfico* (2023), 57-65. doi: 10.35992/pdm.5vi1.1843.

GEOTECHNICS AND ARCHITECTURE. CONSIDERATIONS ON THE CURRENT GEOTECHNICAL PARADIGM AND ITS POSSIBLE FUTURE DEVELOPMENT

Emilio Gastón Polo Friz
National University of Mar del Plata (Argentina)
emilio_polo@hotmail.com - https://orcid.org/0000-0001-9283-5790

Summary. The understanding of soil behavior is a key element for the development of both architectural works and urban infrastructures, since most of the failures in constructions are related to the relative ignorance of the nature of the soil. Considering the heterogeneous and complex nature of soil, can geotechnical engineering - by today's standards - achieve an understanding of the soil/built dynamics? or is a paradigm shift required, with input from other disciplines, to enable the articulation of more complex and accurate models? The objective of this research is to explore the current paradigm in soil mechanics and to expose possible future scenarios for the discipline, from a quantitative-qualitative methodological design and using data collection techniques; systematization on a Geographic Information System (GIS); with determination of characteristic features -with interpretative and descriptive analysis- of the support structure, we sought to determine the characteristic features of the different types of soils found in the city of Mar del Plata, Republic of Argentina, establishing differentiated geotechnical characterization zones. At present, there are lines of research that seek the development of mathematical models to describe a realistic soil behavior; where, with regard to the lack of data - it is important to note that, although there is currently a large amount of data available from different disciplines, such information is not cross-cutting and interrelated - the incorporation and systematization of such data continues to be the greatest difficulty.

Key words: Urban planning, management instruments, public policies, geotechnics and soil mechanics.

GEOTECNIA Y ARQUITECTURA. CONSIDERACIONES SOBRE EL PARADIGMA ACTUAL EN GEOTECNIA Y SUS POSIBLES DESARROLLOS FUTUROS

Emilio Gastón Polo Friz

Resumen. La comprensión del comportamiento del suelo es un elemento clave para el desarrollo tanto de obras de arquitectura, como de infraestructuras urbanas; ya que la mayor parte de los fallos en las construcciones, están relacionados con el desconocimiento relativo de la naturaleza del suelo. Teniendo en consideración la naturaleza heterogénea y compleja del suelo, ¿puede la geotecnia -según estándares actuales- lograr una comprensión de la dinámica terreno/obra construida? ¿o se requiere un cambio de paradigma con aporte de otras disciplinas, que permitan articular modelos más complejos y precisos? Siendo el objetivo de la presente investigación, el de explorar el paradigma actual en mecánica del suelo y exponer posibles escenarios futuros superadores para la disciplina, desde un diseño metodológico de tipo cuantitativo-cualitativo y utilizando técnicas de recopilación de datos; sistematización sobre un Sistema de Información Geográfica (GIS); con determinación de rasgos característicos -con análisis interpretativo y descriptivo- de la estructura soporte, se buscó determinar los rasgos característicos de los diferentes tipos de suelos encontrados en la ciudad de Mar del Plata, República Argentina, estableciendo zonas de caracterización geotécnica diferenciada. En la actualidad, existen líneas de investigación que buscan el desarrollo de modelos matemáticos que permitan describir un comportamiento realista del suelo; donde, en lo que refiere a la carencia de datos -siendo importante destacar que, si bien en la actualidad existe una gran cantidad de datos disponibles de diverso origen disciplinar, dicha información no se transversaliza e interrelaciona- la incorporación y sistematización de los mismos, sigue siendo la mayor dificultad.

Palabras clave: Planificación Urbana, instrumentos de gestión, políticas públicas, geotecnia y mecánica de suelos.

Introduction

The understanding of soil behavior is a key element for the development of both our architectural works and the civil engineering infrastructures required by a city or region; since, as Brandl (2004) indicates, 80-85 percent of construction failures are related to changes in the dynamics of the supporting structure, its behavior and the emerging stresses that may occur with the constructions that are built on it.

Thus, any uncertainty regarding the nature of the soil, the geotechnical conditions of a city, or the dynamics between the constructed work and the territory on which it is located, are mainly due to the difficulty in obtaining and analyzing data on the subsoil and its interaction with the constructions. This is why, in recent years, the strategic management of the subsoil has come to represent a topic of relevance for the development of cities, constituting a new interdisciplinary field known as "urban geosciences".

The city of Mar del Plata, Province of Buenos Aires, Argentina, like most of the main capitals in Latin America, has developed its urban planning without taking into consideration basic factors of territorial structuring, such as geology and geotechnics, thus ignoring its vulnerable areas and/or sectors of potential geotechnical risk.

In this sense, the absence of a well-founded and systematized knowledge about the behavior of Mar del Plata's soil makes the correct implementation of instruments for the design and execution of municipal development policies, as well as the adequate

implementation of architectural and civil engineering works of medium and high complexity, very difficult.

On the basis of the problems described above, Arq. Emilio Polo -author of the present work- has been developing his doctoral thesis at FAUD-UNMdP, which aims -from the collection of existing data and its systematization on a Geographic Information System (GIS)- to determine the characteristic features of the different types of soils present in the city of Mar del Plata; establishing differentiated geotechnical characterization zones (areas with potential for urban development, geotechnical risk zones, etc.) in order to offer new knowledge in the field of local geotechnics, focused on the dynamics of the Mar del Plata soil, its interaction with the architectural work -built and to be built- and the different foundation alternatives used. As part of this work, and based on the conceptual limitations found on the knowledge of soil behavior -and taking into consideration its heterogeneous and complex nature-, can geotechnical engineering -according to its current standards- achieve a complete understanding of the soil/built dynamics? or is a paradigm shift required that draws from the various disciplines and allows for the articulation of more complex and accurate models?

Method

The research developed, from a quantitative-qualitative methodological design with interpretative and descriptive analysis, has used techniques related to data collection (soil studies, satellite images, geo-referenced information, etc.); systematization of information on a Geographic Information System (GIS); and determination of characteristic features of the city of Mar del Plata; establishing on this, differentiated geotechnical characterization areas (areas with potential for urban development, geotechnical risk areas, etc.).

For this article, a descriptive and interpretative methodology of documentary analysis on secondary sources has been used, where the evolution of geotechnics as a science in the course of time is analyzed, as well as the development of its principles and paradigm changes. As established by Denzin and Lincoln (2017), the integration of methodological instruments, the documented, the observed and the conversed, lead to the recursivity of analysis, synthesis and interpretation processes that enable different perspectives on the same reality.

Results

Soil science seeks to understand its nature, properties, dynamics and functions as part of a multidimensional system that includes physical, chemical and mechanical aspects, but also analyzes -or should analyze- the impact of social, urban development, economic and territorial aspects, in relation to how they influence or affect its behavior as a support structure.

In this context, we cannot ignore the fact that soil dynamics is complex due to its heterogeneous and diverse nature, where its original structural composition coexists with endogenous and exogenous variables that condition its response -affecting its performance, in geotechnical terms-. The interaction of solid particles with the interstitial

fluid -which is generally composed of more than one fluid: water, organic and inorganic contaminants, gases, etc.-, the interaction of solid particles with the interstitial fluid, which is generally composed of more than one fluid: water, organic and inorganic contaminants, gases, etc., triggers different behaviors depending on the variation of moisture levels, shape and structure of the granular particles, their heterogeneity, confinement, etc.; where human activities - urbanization processes, transformation of the natural landscape/territory, incorporation or modification of "loads" through the construction of architectural or engineering works - affect the original conditions of the soil, transforming it.

Throughout history, as part of this process of understanding soil mechanics, there has been an ongoing concern to "explain" the fundamentals of soil behavior. From the consideration of failures as "acts of God" (Morley, 1996) to the application of the "law of retaliation" in the Code of Hammurabi - from a legal principle of retributive justice, which have laid the foundations of current codes - to the development of geotechnics as a science in the last part of the 19th century and first half of the 20th century. During the 18th century, we can find the development of the first theoretical numerical models that try to explain the behavior of structures using deterministic concepts.

However, it was not until the second half of the 20th century, with the incorporation of probabilistic concepts, that determinism began to be questioned; where the work built -or to be built- began to be developed taking into account a context where the physical-constructive aspects of the materiality -where the support structure that makes up the territory is located- are dynamic and liable to change.

In this sense, as proposed by Antonio Gens Solé (2005) in his speech to the Royal European Academy of Doctors, contributions such as those made by Coulomb (1736-1806) with the calculation of earth thrust on walls and the analysis of friction phenomena; the contributions of Rankine (1820-1872) with the development of his investigations on limit equilibrium states in a semi-infinite earth mass; and the contribution of Boussinesq (1842-1929) with the solution of the elastic problem of a point load placed on a semi-infinite isotropic elastic half-space; as well as other researchers such as: J.R. Perronet (1769) who provides the first study on slope stability; G.C. Prony (1802), J.F. Français (1820), C.V. Poncelet (1840) and C. W. Hope (1845) who work on earth and wall overpours; A. Collin (1846) who discovers the undrained shear strength of clays; H.P.J. Darcy (1856) who proposed the law of flow in a porous medium that has withstood all the ravages of time; O. Reynolds (1887) who discovered the dilatancy of sands; allowed to lay the foundations of Geotechnics as a science at the dawn of the twentieth century.

The understanding -and formulation of the principle- of effective stresses for saturated soils proposed by Terzaghi in the 1920s, was one of the great contributions to the discipline, where the consideration of soil as a porous material (unlike Coulomb and Rankine who considered it as a solid) allowed him to advance where they could not. Terzaghi himself, from his numerous publications -produced between 1936 and 1961- that address the disconnection between the codes and standards of the time with the technical foundations (what Terzaghi calls "the old code" in reference to the ideas of the early twentieth century), is the one who proposes a first paradigm shift that brings him closer to the discipline as a science.

The principle of effective stresses implied - for the time - a great unification of the hydraulic and mechanical aspects of soil behavior, but the rupture was still considered separately (developments from the works of Coulomb and Rankine), which did not allow the integration of the soil behavior as a coherent whole. In pursuit of this objective, the

Cambridge University Geotechnical group (Roscoe, Schofield and Wroth in the 1960s) set out to achieve a unified model that would allow linking aspects of ground behavior that - at that time - were separate entities, incorporating the concept of critical state and later, the concept of mixed fluid phase and unsaturated soils (Bishop, Aitchinson, Fredlund and Morgenstern in the second half of the 1960s).

Around the same time -1968-, Roscoe and Burland proposed the Modified Cam-clay model, which corrected some important defects of the original Cam-clay, giving rise to the critical state models. These models allowed considering a large number of soil behavior characteristics in a unified way, concepts such as breakage, deformation, volume changes, soil memory, consolidation, critical state could be integrated in a model that allowed a more global understanding of soil behavior.

While it is true that the paradigm represented by the critical state models has been able to satisfactorily characterize some of the most common behaviors of soils, when looking at the actual behavior of many natural soils, we find that the Cam-clay model is often oversimplified, requiring amplification for its effective use.

In this sense, the different soil classifications currently existing are intended to describe and integrate the main characteristics and behaviors of the soil according to the needs of different activities or disciplines -road and pavement construction, agriculture, mining, geomechanics, geology, etc.-, but so far no unified general classification has been achieved.

Some of the classifications that can be referenced are:

1) The Unified Soil Classification System -SUCS-.
2) The American Association of State Highway & Transportation Officials (AASHTO) System.
3) The method proposed by the Federal Aviation Administration -FAA-.
4) The US Department of Agriculture (USDA) system.
5) and the Eurocode taxonomy, among others.

At present, there are several lines of research that seek the development of mathematical models that allow describing a realistic behavior of the soil, facing to a great extent -these systems-, the unpredictability resulting from the uncertainty due to the variability of action of the material, according to the change of the conditions in which it is immersed -changes in humidity levels, higher loads, etc.-.

As stated by Baecher & Christian (2003), sources of uncertainty, in general, can come in three main categories:

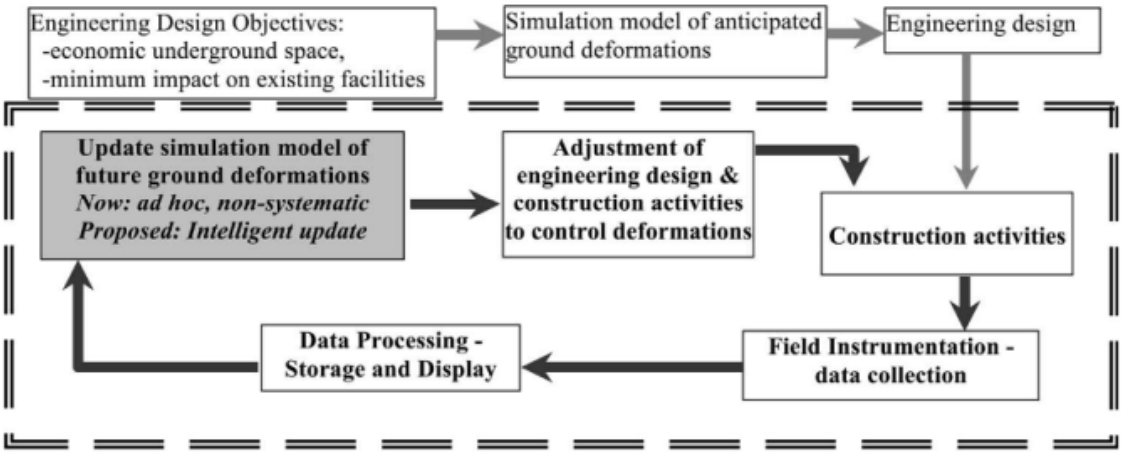
- Those related to natural variability.
- Those related to epistemic uncertainty.
- Those related to decision models.

The first category is related to the variability of soil material behavior due to its heterogeneity and dynamics of change.

Epistemic uncertainty refers to the lack of data or lack of understanding of the emerging physical processes; where the uncertainty in the decision models is determined by the methodology of data interpretation and the achievement of instruments that produce models that produce realistic behaviors.

Figure 1

Systematic procedure of the observational method



Note. Source: Hashash, Marulanda, Ghaboussi, & Jung (2006).

In this sense, any uncertainty related to geological and geotechnical conditions is mainly due to the difficulties in obtaining, selecting and systematizing subsurface data, its heterogeneity and its mechanical dynamics. Therefore, a multidisciplinary approach to data analysis becomes essential.

In line with this framework for action, in recent years, the strategic management of the subsoil of cities has come to represent a topic of relevance for the development of cities, constituting a new interdisciplinary field known as "urban geosciences". This new discipline studies the geological environments of cities in order to provide a scientific basis for rational use in city planning and development.

Where, the advancement of geotechnical science, in addition to the need to propose a global soil classification system, faces the enormous challenge of developing new realistic predictive models that can accurately mimic the behavior of natural and/or modified soils, in each of their conditions -saturated, unsaturated- taking into consideration the influences of the environment, external and internal agents, etc., as well as their interaction with the built object -architectural/civil engineering work-.

Discussion and conclusions

The complexity of the nature of the soil -and the dynamics of its emergent behavior, product of extrinsic and intrinsic factors- has meant that progress in understanding it -in global terms- has been limited, despite the new tools available in terms of exploratory methods.

Currently, most of the surveys are based on vertical unidimensional profiles, where the information obtained is partial and of local use -and/or regional at best-, where the integration of the information through its systematization, in an intelligent database, is far from being extended.

The integration of quantitative information, observational information, and mathematical models -descriptive and predictive-, is a line of research that has been approached in a limited way and that could contribute great advances to the understanding and development of predictive instruments for the realistic behavior of soil dynamics. At present - and thanks to the massiveness of digital media in all its forms - there is a large amount of data available from different disciplinary origins, which describe or provide information on the soil in multidimensional perspectives - physical, chemical, mechanical -; this information is often not taken into account because it is not systematized, cross-cutting and interrelated in unified systems of global use.

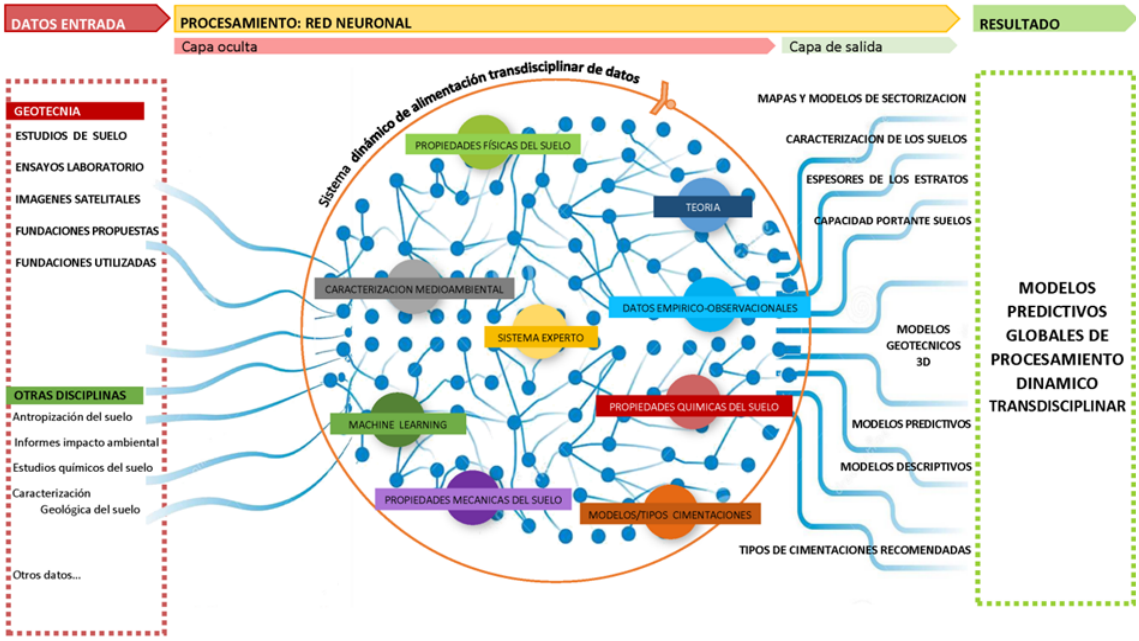
In the era of information technologies, the use of Artificial Intelligence - from its contribution in terms of machine learning, pattern recognition and deep learning - emerges as an indispensable tool to link ground behaviors in macroscopic terms, with the microscopic and nano; the local with the regional and global; scientific theory with the empirical-observational; proposing -or requiring- new measurement systems, where the information obtained is systematized in three-dimensional dynamic models of global scope.

In this sense, A.I. algorithms have already been used with great success in various fields. have already been used with great success in various fields of the discipline, as established by Levasseur, Malécot, Boulon, & Flavigny (2008) for the characterization of soils from dilatometer tests; in the analysis of rock mass strength parameters, according to Ling, Zhang, Zhu, & Tang (2008); for the analysis of earth dams, as reported by Yuzhen, Bingyin, & Huina (2007); or as reported by LI & others (2006) for tunnel analysis; among many other possible applications.

These Artificial Intelligence systems allow to interrelate in a single instrument, components as dissimilar as the empirical -emerging from the practice and observation of the natural environment and its behavior-; the theoretical -as a scientific basis-; the descriptive models of the possible types of soils and their characterization; the mathematical and predictive models; the emerging dynamics between the physical, mechanical and chemical characteristics; where such instrument, can and should -preferably, in order to obtain more complete, complex and closer to reality- obtain more complete, complex and closer to reality models; the mathematical and predictive models; the emerging dynamics between physical, mechanical and chemical characteristics; where this instrument can and should -preferably, in order to obtain more complete, complex and closer to reality models- be fed with dynamic data from the various disciplines whose object of study is the soil, or its interaction with it.

Figure 2

Artificial Intelligence structuring scheme specific to geotechnical development, of neural type with incorporation of transdisciplinary information



Note. Own elaboration.

Bibliography

Bárcena, A. and Romo, M.P. (1994). *RADSH: Computer program to analyze horizontally stratified soil deposits subjected to random dynamic excitations*. Internal report of the Institute of Engineering, UNAM.

Baecher, C. & Christian, J.T. (2003). *Reliability and Statistics in Geotechnical Engineering.* England. John Wiley & Sons.

Cal, Y. (1995). Soil Classification by Neural-Network. *Advances in Engineering Software, 22*(2), 95-97

Brand, E.W. (1981). Investigations for the restoration of the Phra Pathom Chedi pagoda. In *Proc. 10th. Int. Conf. Soil. Mech.* Stockholm, (pp. 853-854).

Brandl, H. (2004). *The Civil and Geotechnical Engineer in Society: Ethical and Philosophical Thoughts, Challenges and Recommendations.* The Deep Foundations Institute, Hawthorne.

Casagrande, A. (1960). Translation of Introduction to Erdbaumechanik auf Bodenphysikalischer Grundlage (1925). In *From theory to practice in soil mechanics*. Wiley, New York.

Cook, G. (1951). Rankine and the theory of earth pressure. *Géotechnique, 2*, 271-279.

Denzin, N. & Lincoln, Y. (2017). *The art and practice of interpretation, evaluation and presentation*. Gedisa Editorial.

Forero Dueñas, C. (1994). Basic Geotechnical Zoning Concepts and Methodology. In *V Colombian Congress of Geotechnics*. Medellín.

García, S.R., Romo, M.P., Figueroa-Nazuno, J. & Ramos, A. (2001). A RPs Approach for the Modelling of Mexico City Ground Motions. In *12th European Conference on Earthquake Engineering*. Elsevier Science Ltd.

Gardner, M.W. & Dorling, S.R. (1998). Artificial neural networks (The multilayer perceptron) - A review of applications in the atmospheric sciences. *Atmospheric Environment, volume 32* (14/15), 2627- 2636.

Goh, A. T. C. (1994). Seismic Liquefaction Potential Assessed by Neural Networks. *Journal of Geotechnical Engineering*, *120*(9), 1467-1480

Goh, A. T. C., Wong, K. S., & Brons, B. B. (1995). Estimation of Lateral Wall Movements in Braced Excavations Using Neural Networks. *Canadian Geotechnical Journal,* 32(6), 1059-1064.

Kurkova, V. (1992). Kolmogorov theorem and multilayer neural networks. *Neural Networks, 5*(3), 1-5.

Lambe, T.W. & Whitman, R.V. (1968). *Soil Mechanics*. Wiley. N.Y.

Levasseur, S. (2008). *Analyse Inverse en Géotechnique; développement d'une méthode a base d'algorithmes génétiques*. Grenoble.

LI, X. (2006). *Intelligent Back Analysis of Tunnel Rock Displacement and Its Application.* Underground Space.

Ling, X., Zhang, F., Zhu, Z., & Tang, L. (2008). *Estimating mechanics parameters of rock mass based on improved genetic algorithm*. IEEE.

Millar D L and Clarici E, (1994). Investigation of Backpropagation Artificial Neural Networks in Modeling the Stress-Strain Behavior of Sandstone Rock. In *IEEE International Conference on Neural Networks*. IEEE Service Center.

Romo, M. P., Rangel, J. L., Flores, O., & García, S. R., (1998). Application of artificial neural networks to geotechnical engineering. In *XIX National Meeting of Soil Mechanics*. Puebla, Mexico, 418-427.

Santamarina, J.C. (2003). Creativity and Engineering-Education Strategies. In *Int. Conference on Engineering Education in Honor of J.T.P.* Yao, Texas (pp. 91-108).

Santamarina, J.C. (2006). Geotechnology: Paradigm shifts in the Information Age. In *GeoCongress 2006 Geotechnology in the Information Age*. LG Baise, Eds.

Sarmiento, N. (2001). *Evaluation of seismic response in the Valley of Mexico applying artificial neural networks*. [Master's Thesis], DEPFI, UNAM, Mexico

Savioli, C. (1978). *Soil and Foundations*. Espacio Editora.

Solé, A. G. (2005) *Geotecnia: A Science for Ground Behavior*. Royal European Academy of Doctors.

Wong, F., Tung, A., & Dong, W. (1992). *Seismic hazard prediction using neural nets*. In *10th World Conference on Earthquake Engineering*, (pp. 339- 343).

Yuzhen, Y., Bingyin, Z., & Huina, Y. (2007). An intelligent displacement back-analysis method for earth-rockfill dams. *Computers and Geotechnics*, 423-434.

Zurada, J.M. (1992). *Introduction to artificial neural systems*. West Publishing, St. Paul.

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:
Forte Silva, M. V. & Garat de Marín, M. S. (2023). Método FORTE v. 1.0: una contribución a la gestión de megaproyectos de ingeniería en Brasil. *Project, Design and Management,* número monográfico, 66-80. 10.35992/pdm.mo2023.2114.

FORTE METHOD V. 1.0: A CONTRIBUTION TO THE MANAGEMENT OF ENGINEERING MEGAPROJECTS IN BRAZIL

Marcus Vinícius Forte Silva
European University of the Atlantic (Spain)
marforte@gmail.com - https://orcid.org/0009-0007-0591-728X
Mirtha Silvana Garat de Marín
Universidad Internacional Iberoamericana (Uruguay)
silvana.marin@unib.org - https://orcid.org/0000-0003-3044-8087

Summary. The changes brought about by globalization have created a new reality for the means of production and communication, quality of life and behavior, favoring the emergence of projects all over the world. During the Workers' Party government (2003-2016), Brazil followed this trend, transforming itself into a major construction site, where oil and gas exploration engineering assumed an important role for the national economy. The high world energy demand and the discovery of the pre-salt province would allow the country to become an energy exporter and superpower by 2030, defining the strategic nature of the oil and gas exploration megaprojects in the Santos Basin, São Paulo. The government program in the PT era offered Brazil fertile ground for economic development, but also for illegality, when a new reality brought to light in 2014 by Operation Car Wash unleashed the biggest corruption scandal in Brazil's history. The combination of complexity and corruption led to delays in the delivery of oil to the consumer market and huge financial losses. The situation called for initiatives to support schedule management that are up to the challenge, where the expected response is the application of a schedule analysis method - the FORTE v Method. 1.0 - responsible for the first integrated initiative aimed at compliance, project management and corporate knowledge, adjusted to the reality of large engineering projects in Brazil. The situation required an IT solution with different characteristics - Oracle Primavera P6 - and the result of the initiative is a set of achievements beyond project management, permeating the entire organizational fabric.

Key words: Engineering, megaprojects, compliance, FORTE v. Method. 1.0, Oracle Primavera P6.

MÉTODO FORTE V. 1.0: UNA CONTRIBUCIÓN A LA GESTIÓN DE MEGAPROYECTOS DE INGENIERÍA EN BRASIL

Resumen. Los cambios provocados por la globalización han construido una nueva realidad para los medios de producción y comunicación, la calidad de vida y el comportamiento, favoreciendo el surgimiento de proyectos en todo el mundo. Durante el gobierno del Partido de los Trabajadores (2003-2016), Brasil siguió esta tendencia, transformándose en un gran sitio de construcción, donde la ingeniería de exploración de petróleo y gas asumió un papel importante para la economía nacional. La alta demanda mundial de energía y el descubrimiento de la provincia del presal permitirían al país convertirse en exportador de energía y superpotencia para el año 2030, definiendo el carácter estratégico de los megaproyectos de exploración de petróleo y gas en la Cuenca de Santos,

São Paulo. El programa de gobierno en la era del PT ofreció a Brasil un terreno fértil para el desarrollo económico, pero también para la ilegalidad, cuando una nueva realidad sacada a la luz en 2014 por la Operación Lava Jato desencadenó el mayor escándalo de corrupción en la historia de Brasil. La combinación de complejidad y corrupción provocó retrasos en la entrega de petróleo al mercado de consumo y enormes pérdidas financieras. La situación exigía iniciativas de apoyo a la gestión de horarios que estén a la altura del desafío, donde la respuesta esperada es la aplicación de un método de análisis de horarios – el Método FORTE v. 1.0 – responsable de la primera iniciativa integrada dirigida al cumplimiento, gestión de proyectos y conocimiento corporativo, ajustada a la realidad de los grandes proyectos de ingeniería en Brasil. La situación requería una solución de TI con diferentes características – Oracle Primavera P6 – y el resultado de la iniciativa es un conjunto de logros más allá de la gestión de proyectos, permeando todo el tejido organizacional.

Palabras clave: Ingeniería, megaproyectos, cumplimiento, Método FORTE v. 1.0, Oracle Primavera P6.

Introduction

Project management has been gradually imposing its value on human achievement. From the pyramids of Giza to the conquest of space, a new understanding of the challenges and applicable practices emerges, offering nations a new perception of needs, values and redress of man-made grievances.

The globalization process in Brazil that occurred with neoliberalism in the 1990s imposed important economic, political and social changes, leading to a global system of causes and effects. As consequences, there is fierce competition and reduction of production costs, scientific-technological exchange, increased quality of life and longevity, creation of specialized jobs and demand for professional qualification, universalization of access to the media and, as a highlight, the formation of a global culture that is competitive, collaborative and aware of the weight of innovative, sustainable and culturally diverse ideas (Khan, 2018, p. 8). The new current of thought is influencing the most recent discussions on management, where today's man is presented with a new set of values, opportunities, resources and traits to overcome. Once this perception is broadened, it fuels the concern and need for growth and transformation, demanding projects in the various areas of human knowledge, including the generation of energy through oil and gas exploration. Globalization is a reality with repercussions today, a process that should neither be praised nor rejected, representing only a challenge for which Brazil must be prepared (Sardenberg, 1999, pp. 42-49), profoundly and irreversibly modifying the scenario of public and private projects.

In the governments of Luís Inácio da Silva (2003-2011) and Dilma Rousseff (2011-2016), both from the *Workers' Party* (*Partido dos Trabalhadores, PT*), Brazil followed the global trend towards development, instituting projects in different sectors of the economy throughout the national territory. The discovery of the Brazilian pre-salt province in 2007, a region with oil and gas in high volume and quality standards, added to the high world energy demand in 2014, would allow Brazil to become an exporter and energy power until 2030. The pre-salt province covers an area of 160,000 km2, equivalent to 12 times the area of the city of Rio de Janeiro, extending from the coasts of Santa Catarina to Espírito Santo, in addition to the sedimentary basins of Espírito Santo, Campos and Santos, concentrating 55% of the Brazilian gross domestic product (Figure 1).

Figure 1

Brazilian pre-salt province

Note. Source: G1, 2015.

Oil and gas exploration engineering began to assume an important role in the national economy, where the strategic nature and high complexity of the portfolios required large investments in Research, Development and Innovation (R&D&I), in addition to differentiated management.

Government programs in the PT era offered Brazil economic and social development like never before, despite the strong presence of illegality at all levels. Meanwhile, Brazil's Federal Police launched Operation Lava Jato in 2014, triggering the biggest corruption and money laundering scandal in the country's history. The consequences of the operation drew the attention of the world media, the arrest of top executives of public and private companies, and the impeachment of President Dilma Rousseff.

According to Dan Ariely, professor of psychology and behavioral economics at *Duke University*, USA, the company's growth is expected to continue. The U.S. researcher and director of the *Center for Advanced Hindsight*, in a survey involving more than 40,000 participants from different countries, identified that 70% of the participants cheated, noting: (i) dishonesty is inherent to the human being; (ii) individuals seek to walk on the borderline between the advantages acquired with dishonesty, without damaging the self-image of probity; (iii) the ethical-moral conduct of the individual is influenced by social forces, being inhibited or encouraged by the group to which he belongs; (iv) honesty requires effort and self-awareness; (v) physiological damages (physical and mental fatigue, sleep, hunger, etc.) subject the individual to choose shortcuts or more attractive options that favor dishonesty (passing traffic lights, jumping the queue, etc.); and (vi) the amount of dishonesty does not subject the individual to choose shortcuts or more attractive options that favor dishonesty (passing traffic lights, jumping the queue, etc.).) subject the individual to choose shortcuts or more attractive options that favor dishonesty (passing traffic lights, jumping in line, etc.); and (vi) the amount of dishonesty does not vary with the change in the amount of benefits from the illicit act and the probability of punishment does not have a substantial influence on the amount of illegality. However, as the rationalization (softening) of dishonesty goes beyond the line of morality, the volume of wrongdoing tends to increase (Ariely, 2012).

According to the *Global 2020 Report*: *Cost of Insider Threats*, insider threats to companies are growing worldwide. The report clarifies that 72% of the frauds affecting

companies involve an internal collaborator and half of the companies in the world have already suffered attacks. Employees are classified into 3 types: (i) careless or negligent employees or contractors, accounting for 62% of incidents; (ii) criminal (or malicious) infiltrator with 23% of incidents, costing organizations an average of $755 760 per incident; and (iii) credential thief with 14%, costing each organization an average of US$2.79 million (Ponemon Institute, 2020). In this context, threats can arise from unintentional mistakes by internal employees, targets of external actors in the use of their privileges, or even dissatisfaction, leading to the use of internal privileges to the detriment of the company, personal vendettas, or leakage of data and secrets for personal gain.

Operation Car Wash (Operação Lava Jato) raised concerns in Brazilian society about the impacts of corruption and the direction of the country. The new scenario imposed on Brazilian organizations the adoption of integrity and anti-corruption programs. According to a KPMG survey, in 2015, 57% of the 250 companies interviewed in Brazil reported having ethics and compliance programs and policies. In 2016, the number increased to 76% and, in 2017, it reached 95%. Concern grew over the rigidity of the sanctions and the impacts on the image of the companies involved (Monteiro and Kertesz, 2018, p. 17).

The national corruption scenario reached the oil exploration megaprojects environment, causing significant delays in the delivery of oil and gas to the international consumer market and huge losses for the Brazilian government. As a result, the bar chart - Gantt chart - receives the *status of the most important project document*, a centralizer of information and management decisions. In this sense, the FORTE Method v. 1.0 provides the schedule with quality and compliance for timely analysis to reverse problems in megaprojects. The situation does not require project management, but *project leadership* (Merrow and Nandurdikar, 2018, pp. 14-16), based on technical skills and, mainly, different emotional skills, shaping a *compassionate leadership*. Among the top 5 emotional skills: (i) *Emotional stability* (low neuroticism); (ii) *Openness* to curiosity, new experiences, and breaking paradigms in order to conceive new ideas; (iii) *Scrupulousness* through self-discipline oriented toward duties and goals; (iv) *Extroversion* of positive emotions, tendency toward stimulation and companionship; and (v) *Kindness* through compassion and cooperation with others, respecting individual differences and social harmony (Merrow & Nandurdikar, 2018, p. 33; Goldberg, 1992) (Figure 2).

Figure 2

Project Leader Skills according to Lewis R. Golberg's Big Five (1992).

Objectives

In the scenario presented, in order to guarantee the bar programs - Gantt charts - in quality and compliance for the follow-up and control of Oil and Gas engineering megaprojects, the FORTE v. method was created. 1.0, an initiative for the integrated analysis of schedules according to the Brazilian reality. To this end, the objective was: (i) ensure an accurate analysis of the problems in the schedules; (ii) identify the pillars of the method; and (iii) highlight the contribution of the method to the success of megaprojects, stakeholders and organizational knowledge.

Method

The *delimitation* considered organizational climate analysis and schedule management, taking into account the dependencies (world situation, country, etc.).

The *research techniques* involved action research, projective, applied, mixed, exploratory, exploratory, cross-sectional with time perspective (August 2013 to October 2015) (Figure 3).

Figure 3

Operational cycle of projective research

Note. Source: Adapted from Barrera, 2010.

The *techniques* were applied according to 5 classes of analysis: (i) C1 - Global (energy sector, opportunities, threats, etc.) and Country (politics, economy, society, technology, legal, etc.); (ii) C2 - Organization (mission, vision, values, etc.); (iii) C3 - Organizational environment

(culture, climate, etc.); (iv) C4 - Project, program and portfolio management (structure, model, maturity, problems, etc.); (v) C5 - Method validation (Table 1).

Table 1
Research techniques, types, levels and tools of analysis

Research technique	Class	Level of analysis	Analysis instrument
Indirect documentation: bibliographic research.	C1	Global: sector, ranking of producers and consumers, opportunities, threats, etc.	KISS/ PESTLE/ SWOT
		Country: politics, economy, society, technology, legal, etc.	
Indirect documentation: documentary research.	C2	Organization: general data (mission, vision, values, market share, etc.).	
Direct documentation: combined exploratory-descriptive studies.	C3	Organizational environment: specific data (behavior, culture, climate, etc.).	
Intensive direct observation: asystematic observation.	C4	Project, program and portfolio management: general data (management structure, problems, etc.).	KISS/ SMART/ RASCID/ GUT/ 5 Whys/ Pareto/ Business Process Mapping/ SDCSLA/ etc.
Direct documentation: program evaluation studies.	C5	Validation of the final product: integrated schedule analysis method.	

The *study units* included: (i) Globalization; (ii) Corporate Governance; (iii) Ethics and Compliance; (iv) Organizational Behavior; (v) Psychology and Behavioral Economics; (vi) Project Complexity; (vii) Project, Program and Portfolio Management; and (viii) Project Management Software.

The *bibliographic review* considered the investigative, projective, temporal and multidisciplinary nature of the subject, requiring a longer period of coverage - 1996 to 2022 -, from the scientific construct to the final product, and observed: (i) internal documents; (ii) renowned authors; (iii) professional associations; (iv) specialized media; (v) technical consultancy; and (vi) solution manufacturers.

The projective research learned about the innovation of the proposal, according to technical and behavioral criteria, scoring information from August 2013 to October 2015, namely: (i) project life cycle (pre-project; project initiation; project organization and preparation; project work execution, project closure and post-project); (ii) project management process groups (initiation, planning, execution, monitoring and control, and closure); (iii) project management knowledge areas (integration, scope, time, cost, quality, human resources,

communications, risk, procurement and stakeholders); and (iv) management levels (strategic, tactical and operational).

Results

The FORTE Method v. 1.0 is initially based on the *implementation requirements* and solution pillars. The requirements for implementation were defined according to groups: (i) *Managerial*: top management support; type of organizational structure (preferably projected organization); full access to project information (including outsourcing); and integration of efforts between internal and external teams; (ii) *Technical-process*: use of Oracle Primavera P6 software; centralized database; transparency, process alignment and traceability of actions; continuous improvement; and centralization of organizational knowledge; (iii) *Behavioral*: respect for cultural differences between the countries involved; and (iv) *Promotional*: attention to change management, from implementation to maintenance of the solution. The pillars contemplate 3 stages, according to the implementation model: (i) governance, analysis and qualification of people (skills and competencies), and viable technologies; (ii) operationalization based on structure, processes and actions for compliance; and (iii) return modalities (payback, stakeholder satisfaction, team performance, organizational knowledge, strengthening of corporate image, others) (Figure 4).

Figure 4

Pillars of the FORTE Method v. 1.0.

The FORTE Method v. 1.0 offered a new perspective on schedule management, disseminating values such as ethics, compliance, quality and merit at different management levels, enabling prevention and deterrence at the source of illegalities, according to Donald Cressey's *Fraud Triangle* : (i) inhibiting the *opportunity for fraud* by creating profiles with varying degrees of schedule interference and action traceability; (ii) neutralizing *fraud*

motivation by empowering teams and recognizing gains for the project; and (iii) reducing *fraud rationalization* by the commitment made between leadership and teams to work collaboratively (Figure 5).

Figure 5

Triangle of Frauds, by Donald Cressey (1953).

According to Peter Drucker: - "Culture eats strategy for breakfast", the origin and the answer to illegality is in the organizational culture, i.e. focused on people, the most promising asset and agent of change of an organization, fitting an attentive look at their needs and achievements (Table 2).

Table 2

Adapted from Abraham H. Maslow's Pyramid of Human Needs (1943).

Needs	Personal	Professionals
Self-realization	Realization of personal potential, self-realization, pursuit of personal growth and peak experiences.	Challenges, participation in decisions, growth.
Estimate	Self-esteem: dignity, achievement, mastery, independence.	Responsibilities, recognition, promotions.
	Reputation: status, prestige.	
Social	Friendship, intimacy, trust and acceptance, receiving and giving affection and love, being part of a group (family, friends, work).	Collegiality, interaction with customers, respect for the boss.
Security	Protection from the elements, security, order, law, stability, freedom from fear.	Safe work, compensation and benefits.
Physiological	Air, food, water, shelter, clothing, warmth, sex, sleep.	Working hours, rest, comfort.

The operationalization of the solution adopted research processes at 2 levels: (i) *FORTE v. Methodology*. 1.*0 and organizational climate analysis* identified the company's scenario and the management of projects, programs and portfolios, supporting actions; (ii) *FORTE v. Method*. 1.*0 and the analysis of the timelines*, identified in detail the problems, traces, indications, clues and evidence leading to the conclusion of the event and the causal agents (Figure 6). To this end, in the initial 3 months, the solution pilot ran with 52 Primavera P6 reports, reaching 75 reports for a sample of 26,000 activities referring to the current oil tanker hull construction schedule (9.63% of the universe) , distributed in 2 groups and 6 analysis categories - (i) *quality* (configurations, modeling and logical network); and (ii) *compliance* (measurement, performance, forensic analysis), with a total of 176,000 data recorded in 19,000 pages of weekly research (Table 3) (Figure 6). In order to optimize reading by top management and the teams, a 40-page diagnostic summary was chosen with the main problems, causes, correction guidelines and glossary to standardize communication, referencing the detailed reports for consultation. The method caught the attention of top management and, being requested both vertically and horizontally, intensified follow-up, communication, team training, among others.

Table 3
Sample data from an oil exploration vessel FPSO

Digital files and activities per work package of the project schedule							
EDT	**Current Files**	**Reference Files**	**Total Files**	**Activs. Current**	**Activs. Reference**	**Total Activs.**	**total Activs.**
Helmet	6	6	12	26.000	26.000	52.000	9,63%
Package I	29	29	58	35.000	35.000	70.000	12,96%
Package II	16	16	32	16.000	16.000	32.000	5,93%
Packages III / IV	19	19	38	103.000	103.000	206.000	38,15%
Package V / Integration	15	15	30	90.000	90.000	180.000	33,33%
Total	**85**	**85**	**170**	**270.000**	**270.000**	**540.000**	**100%**

Initial results of the pilot implementation of the method: (i) greater maturity and transparency in management; (ii) compassionate leadership; (iii) better communication and information support; (iv) greater awareness, satisfaction, collaborative work and increased productivity; (v) identification of the causes of errors (impraxis, imprudence, negligence or malice) and of those responsible for corrective educational measures and/or sanctions (administrative, civil or criminal); (vi) greater control over risks; (vii) reduction of costs due to delays, rework, litigation, fines (contractual, union, government agencies, etc.) and others; (viii) reduction of costs due to delays, rework, litigation, fines (contractual, union, government agencies, etc.) and others; (viii) reduction of costs due to delays, rework, litigation, fines (contractual, union, government agencies, etc.) and others.) and others; (viii) gains in corporate knowledge; and (ix) increased credibility.

Considering the results, the objectives were partially achieved. Non-compliance with some items of the requirements did not allow for the expected gains. The event compromised aspects of communication, quality and compliance. For example, there was a reduction of up to 50% in rework in the internal planning team processes. On the other hand, the low authority of the implementation team and the decentralization of information in the contracted work packages made it difficult to access important data for the project indicators. A comprehensive solution to the megaproject problems would require: (i) unrestricted compliance with the requirements of the solution project; (ii) investment of US$ 70 thousand (R$ 355,000); (iii) implementation period of 6 months (220 hours/month); and (iv) specialized multidisciplinary team (Table 4). The solution proved to be economically viable, representing 0.55% of the daily loss due to delays in the delivery of oil and gas to the international market.

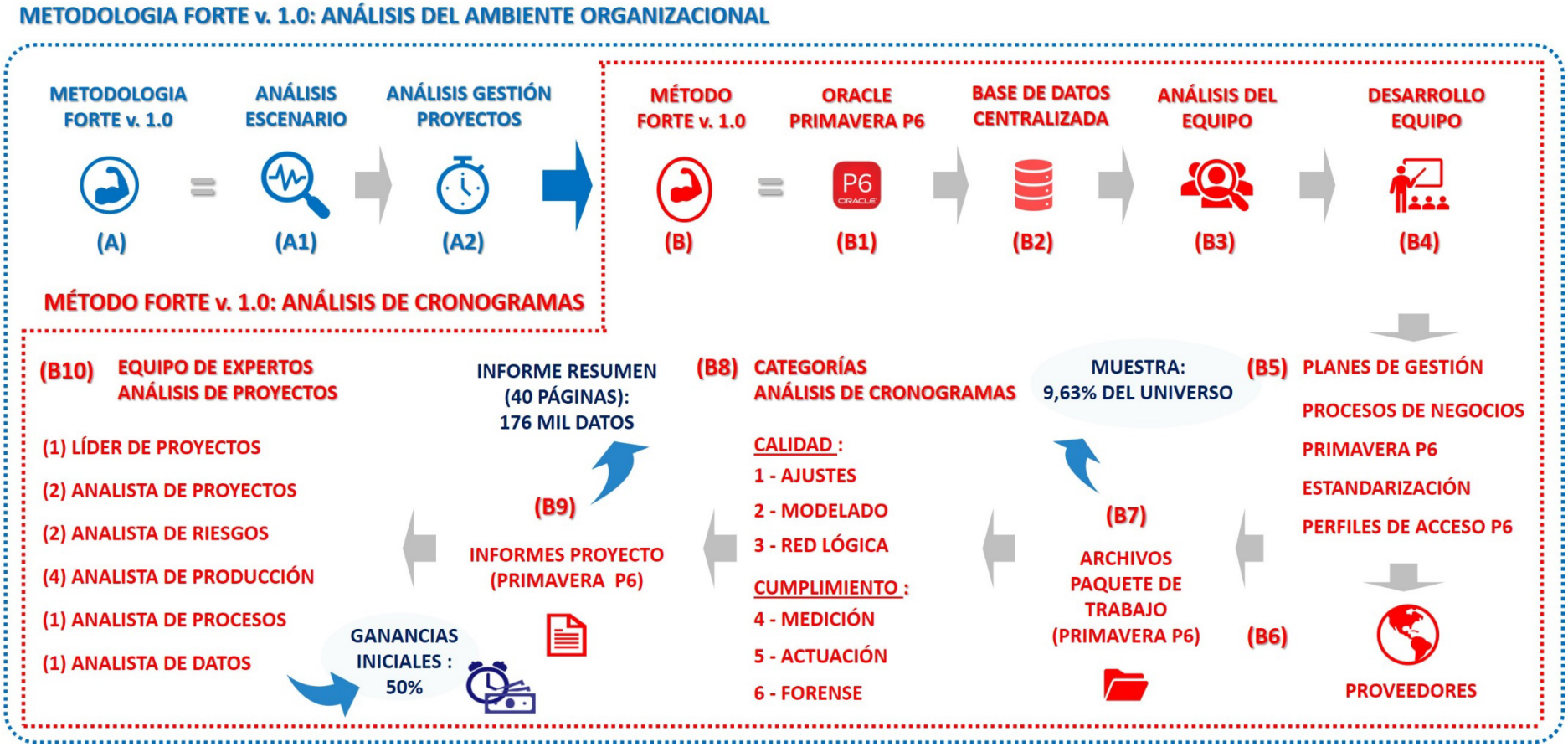
Table 4
Project roles and salaries

Role	Level	Salary/ month	Weekly workload	Wage/hour
Project Management (Contracted)				
Planning and Control Coordinators	Complete	R$ 11.500	44	R$ 52,27
Information and Communication Technology				
Computer Systems Engineer	Complete	R$ 12.500	44	R$ 56,82
Project Management				
Project leader	Master's Degree	R$ 14.500	44	R$ 65,91
Technical Analysis of Projects				
Planning and Cost Engineer	Senior	R$ 13.200	44	R$ 60,00
Risk Engineer	Senior	R$ 13.200	44	R$ 60,00
Production Engineer	Senior	R$ 11.500	44	R$ 52,27
Technical Support for Projects				
OGP analyst, projects and processes	Senior	R$ 6.200	44	R$ 28,18
Business Analytics Intelligence				
Data Specialist	Senior	R$ 13.000	44	R$ 59,09
Business Intelligence Specialist	Senior	R$ 12.000	44	R$ 54,55
Information Security Specialist	Senior	R$ 12.000	44	R$ 54,55
Information Analyst	Complete	R$ 6.100	44	R$ 27,73
Documentation Analyst	Complete	R$ 5.100	44	R$ 23,18
File Manager	Complete	R$ 3.100	44	R$ 14,09
Corporate Education				
Psychopedagogist	Senior	R$ 7.000	44	R$ 31,82
Instructional Designer	Senior	R$ 6.100	44	R$ 27,73

Event Management				
Event designer	Senior	R$ 6.100	44	R$ 27,73
Event Presenter	Complete	R$ 3.500	44	R$ 15,91

Note. The salary surveys refer to January 31, 2022 with quotations for the US dollar (US$) at R$ 5.3568 and the euro (€) at R$ 5.9581. Salaries were adapted to the Brazilian economic context and to the emergence of the solution project. Source: Author, 2022.

Figure 6
Detailed process of the FORTE Methodology and Method v. 1.0.



Conclusions

The *benefits of the method* were recorded in the acronym FORTE: (i) 'F' for *Forecasting* . Make predictions and assumptions of project timelines and costs, allowing for adjustments and better decision making; (ii) 'O' for *Optimization* . To bring about the most cost-effective circumstances for the management, instruments and products of the project; (iii) 'R' for *Reliability (confiabilidade)*. Provide the confidence that project management requires; (iv) 'T' for *Traceability* . Identify indications, traces, footprints, evidence and indications of illegality in the schedules that may lead to evidence and responsible parties; and (v) 'E' for *Enhancement* . To do an excellent and distinctive project management, team training and organizational asset management.

Megaproject leadership is found in the FORTE Method v. 1.0 the ideal support for the quality and compliance required in daily routines, ensuring investigative power, communication and transparency for leadership, senior management, partners and stakeholders in general. It assumes an important role in supporting interface management, agent accountability and continuous training of multidisciplinary teams in projects, where the successful implementation of the method does not allow different interpretations of the established requirements.

The main differential offered by the FORTE Method v. 1.0 is the accurate identification of the source of problems in the schedules, allowing for more realistic and timely corrective actions (Figure 7).

Figure 7
Simplified investigative process of the FORTE Method v. 1.0.

The FORTE method v. 1.0 represents a differentiated solution in a set of achievements beyond schedule management. It permeates the entire organizational fabric and, reflecting the need to bring academia and production closer together, is ideal for conducting international cooperation projects.

References

Ariely, D. (2012). *A mais pura verdade sobre a desonestidade*. Campus/ Elsevier.

Barrera, J. H. de (2010). *Metodologia de la investigación: guía para una comprensión holística de la ciencia* (4ª. Ed.). Quiron Ediciones.

Goldberg, L. R. (1992). *T*he development of markers for the big-five factor structure. *Psychological Assessment, 4*(1), 26-42.

Khan, H. A. (2018). Globalization and the Challenges of Public Administration: Governance, Human Resources Management, Leadership, Ethics, E-Governance and Sustainability in the 21st Century.

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370–396. https://doi.org/10.1037/h0054346.

Merrow, E. W. e Nandurdikar, N. S. (2018). *Leading Complex Projects. A data-driven approach to mastering the human side of project management*. Editora Wiley.

Monteiro, F. & Kertesz, S. (2018). *Doing business in brazil after operation car wash (B)*. https://publishing.insead.edu/case/doing-business-brazil-after-operation-car-wash-b.

Ponemon Institute (2020). *2020 cost of insider Threats Global Report*. https://www.proofpoint.com/us/resources/webinars/2020-cost-insider-threats-global-report

Sardenberg, R. M. (1999). Cenários e perspectivas para o Brasil: o projeto Brasil 2020. *Revista Proposta, 80*.

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management
ISSN: 2683-1597

How to cite this article:

Romero, L. I., Eciolaza, G. O., & Polo Friz, E. G. (2023). Los proyectos de investigación como instrumentos de análisis de políticas públicas. Las políticas culturales multijurisdiccionales y sus modelos de gestión en la ciudad de Mar del Plata. *Project, Design and Management, Monográfico* (2023), 81-88. doi: 10.35992/pdm.5vi1.1845.

RESEARCH PROJECTS AS INSTRUMENTS FOR PUBLIC POLICY ANALYSIS. MULTIJURISDICTIONAL CULTURAL POLICIES AND THEIR MANAGEMENT MODELS IN THE CITY OF MAR DEL PLATA

Laura Isabel Romero
National University of Mar del Plata (Argentina)
arq_lauraromero@hotmail.com - https://orcid.org/0000-0001-7023-5567
Guillermo Osvaldo Eciolaza
National University of Mar del Plata (Argentina)
geciolaza@yahoo.com - https://orcid.org/0000-0001-9877-2006
Emilio Gastón Polo Friz
National University of Mar del Plata (Argentina)
emilio_polo@hotmail.com - https://orcid.org/0000-0001-9283-5790

Summary. The Research Group on Policies and Management of Cultures belonging to the Faculty of Architecture, Urbanism and Design of the National University of Mar del Plata, developed its research proposal with the objective of analyzing the articulation in the research process carried out during its project: Multijuridisional Cultural Policies in the City of Mar del Plata. Comparative Study of Investment and Management Models of the State. Period 2007-2015. From a quantitative-qualitative methodological design, the project presented -as part of the framework of the convergence of public policies of the three levels of the State: national, provincial and municipal, corresponding to the period 2007/2015 in the city of Mar del Plata, Republic of Argentina-, has problematized the political definitions executed separately, in order to analyze to what extent they oppose, neutralize or complement each other in terms of audience construction. The articulation of the three emblematic case studies chosen allowed us to recognize the degrees of development achieved by the social subject as a subject of cultural rights. Currently, the project seeks to socialize the analysis of the emerging processes of public policies that are transversal between jurisdictions, based on understanding the integrality of the territory and the social subject that accesses the agenda of public policies in culture. The theoretical relevance of the research allows providing conceptual content from an interdisciplinary approach to the field of culture.

Key words: Research, public policies, cultural policies, Mar del Plata.

LOS PROYECTOS DE INVESTIGACIÓN COMO INSTRUMENTOS DE ANÁLISIS DE POLÍTICAS PÚBLICAS. LAS POLÍTICAS CULTURALES MULTIJURISDICCIONALES Y SUS MODELOS DE GESTIÓN EN LA CIUDAD DE MAR DEL PLATA

Laura Isabel Romero
Universidad Nacional de Mar del Plata (Argentina)
arq_lauraromero@hotmail.com · https://orcid.org/0000-0001-7023-5567
Guillermo Osvaldo Eciolaza
Universidad Nacional de Mar del Plata (Argentina)
geciolaza@yahoo.com · https://orcid.org/0000-0001-9877-2006
Emilio Gastón Polo Friz
Universidad Nacional de Mar del Plata (Argentina)
emilio_polo@hotmail.com · https://orcid.org/0000-0001-9283-5790

Resumen. El Grupo de Investigación en Políticas y Gestión de las Culturas perteneciente a la Facultad de Arquitectura, Urbanismo y Diseño de la Universidad Nacional de Mar del Plata, desarrolló su propuesta de investigación bajo el objetivo de analizar la articulación en el proceso de investigación llevado adelante durante su proyecto: Las Políticas Culturales Multijuridiscionales en la Ciudad de Mar del Plata. Estudio Comparativo de Inversión y Modelos de Gestión del Estado. Periodo 2007-2015. Desde un diseño metodológico de tipo cuantitativo-cualitativo, el proyecto presentado -como parte del marco de la convergencia de las políticas públicas de los tres niveles del Estado: nacional, provincial y municipal, que se corresponden con el periodo 2007/2015 en la ciudad de Mar del Plata, República Argentina-, ha problematizado las definiciones políticas ejecutadas por separado, con el objeto de analizar en qué grado se oponen, se neutralizan o se complementan en término de construcción de audiencias. La articulación de los tres casos emblemáticos de estudio elegidos, permitió reconocer los grados de desarrollo alcanzados por el sujeto social como sujeto de derecho cultural. En la actualidad, el proyecto, busca socializar el análisis de los procesos emergentes de las políticas públicas que son transversales entre jurisdicciones, a partir de entender la integralidad del territorio y del sujeto social que accede a la agenda de las políticas públicas en cultura. La relevancia teórica de la investigación permite aportar contenido conceptual, desde un abordaje interdisciplinario sobre el campo de la cultura.

Palabras clave: Investigación, políticas públicas, políticas culturales, Mar del Plata.

Introduction

The Research Group on Policies and Management of Cultures, belonging to the Faculty of Architecture, Urbanism and Design of the National University of Mar del Plata, presented its research proposal (2021-2022) at the University: "Multijurisdictional Cultural Policies in the City of Mar del Plata. Comparative Study of Investment and Management Models of the State. Period 2007-2015″ whose objective is to establish the degree of articulation of cultural policies implemented in the city of Mar del Plata.

The research work was carried out based on the study of three emblematic cases of architecture linked to cultural activities: the recovery of the former Saturnino Unzué Institute by the National Ministry of Social Development; the competition, construction and inaugural exhibition of the MAR Museum of Contemporary Art by the Government of the Province of Buenos Aires; the acquisition and conversion of the House on the Stream into a museum by the Municipality of General Pueyrredon.

We consider that the field of research helps to investigate different problems that are subsequently delimited by the researchers. This reality makes it possible to establish areas of interest, objectives, methodology, theoretical framework and state of the art, in addition to establishing the social, cultural and political impact of the research, as well as the possibility of training human resources. Research makes it possible to build scaffolds of new knowledge that, through analysis instruments, establish levels of information tending to construct new categories of analysis.

As a starting point for the research, we consider it necessary to explain some concepts on public policies that have allowed us to advance in the project and to establish the different levels of public policies. In principle, policy is a decision-making process with an ideological orientation that makes it possible to establish objectives, criteria and premises on a particular and/or general issue. In this sense, politics is a tool that allows, from a biased vision (ideological), to propose mechanisms to implement a project.

Oszlak and O'Donnell (1981) consider public policies as: "(...) a set of actions or omissions that manifest a certain modality of intervention by the State, in relation to an issue that arouses the attention, interest or mobilization of other actors of civil society" (p.21). These decisions will generate operations in the territory, intervening, both materially and symbolically, in its structure.

Taking this into account, we can conclude that every public policy has the capacity to be understood as a cultural policy in terms that directly and indirectly affect socio-cultural practices and their forms of appropriation of the territory.

On the other hand, we can establish three guiding categories of public policy: 1. The ideological, 2. the instruments, 3. the actions (Ruiz López and Cadénas Ayala, 2005). Based on these categories, we can find different types of classifications of public policies:

> 1. Substantive and procedural policies. Substantive policies have to do with what the government is going to do (...). Procedural policies have to do with how something is going to be done or who is going to undertake the action. (...). 2. Distributive, regulatory, self-regulatory and redistributive policies. Policies can be classified according to their effect on society and the relationships between the actors involved in their formation. Distributive policies consist of providing goods or services to a certain segment of the population (...). Regulatory policies impose restrictions or limitations on the behavior of individuals and groups (...). Self-regulatory policies are similar to the previous ones because they consist of limiting or controlling some sector or group, but they differ from them in that they are defended and supported by the group as a way of protecting or promoting the interests of its members. (...). Redistributive policies are a deliberate effort by government to change the allocation of wealth, income, property or rights among broad social groups or classes. (...). 3. Material and symbolic policies. (...). Material policies provide tangible advantages or disadvantages. (...). Symbolic policies, on the contrary, have hardly any real material influence on people:

they assign non-tangible advantages and disadvantages (Delgado Godoy, 2009).

In addition, we can categorize public policies - from their stability as a government policy or State policy; - through their territorial scope: national, provincial and/or local (Pérez Antrakidis and Romero, 2022).

On the other hand, the analysis of public policies allows us to know the management and strategies adopted by the State in the face of a problem, as well as to observe whether the issues are part of a public agenda or only a concern of the government administration.

The purpose of this paper is to give an account of the processes, analyses and explorations carried out as part of the research conducted. In this sense, research on multijurisdictional cultural policies and their management models in the city of Mar del Plata became the subject to be investigated, taking into consideration the three levels of the State: municipal, provincial and national. The aim of this article is to analyze the articulation mechanisms in the research process carried out by the Research Group on Policies and Management of Cultures -FAUD, UNMdP- during its project: "*Multijurisdictional Cultural Policies in the City of Mar del Plata*".

Method

The research was developed based on a quantitative-qualitative methodological design, with case study analysis. The case study as a research strategy in the social sciences is "an empirical investigation of a contemporary phenomenon, taken in context, especially when the boundaries between the phenomenon and the context are not obvious" (Yin, 1994, p.13).

The case studies selected by the researchers had to correspond to different levels of the State in the city of Mar del Plata, as well as being home to cultural activities and having been reached by different public policies. "The case study represents a very useful research tool, since it allows to have as a result a holistic approach to a situation or event under study (...) (Escudero Macluf, Delfín Beltrán and Gutiérrez González, 2008, p.10).

In the proposed methodological approach, the integration of the methodological tools, the documented, the observed and the conversed, lead to the recursivity of analysis, synthesis and interpretation processes that enable different perspectives on the same reality (Denzin & Lincoln, 2017).

During the research, different techniques were used: documentary analysis, content analysis and interviews. The primary sources used were interviews with political actors and content analysis, and the secondary sources were information systems, digests and archives of the national, provincial and municipal governments. Among them, we searched the Municipal Official Gazette System (SIBOM) of the Province of Buenos Aires, the library of the Honorable Deliberative Council of the Municipality of General Pueyrredon, the Malvinas Argentinas Regulatory and Documentary Information System of the Province of Buenos Aires and the Official Gazette of the Argentine Republic, as well as the bases of contests and agreements signed with the School of Architecture, Urban Planning and Design. In addition, data from records, documents from national and local newspapers, as well as documents from the researchers' archives were collected.

> The sources are the resources to which we are going to turn and which contain the data (in different media) that we need to extract after using precise intellectual operations in order to obtain knowledge. The alternative is to use the appropriate tools that enable us to produce the data of our direct interest. We need these devices as mediators to achieve (construct, discover or obtain) data and general information (Cicalese and Pereyra, 2016, p. 23).

Results

In the research project elaborated, the framework of the convergence of public policies of the three levels of the State - which correspond to the period analyzed, 2007/2015 -, different governmental strategies on the same territory can be recognized. In this sense, public policies implemented separately have been analyzed in order to determine to what extent they oppose, neutralize and/or complement each other, as instruments for the articulation of intervention strategies and as a response to the needs of the population.

As we have expressed, the case studies selected for the research were emblematic works of the city of Mar del Plata that have different origins, but that fulfill social and/or cultural functions. In order to understand the value of the works, we will describe some characteristics that allow us to understand why they were selected for the analysis of public policies within the framework of the research project.

The former Saturnino Unzué Institute (Figure 1) is a building constructed in 1910 with the purpose of fulfilling a social function as an asylum for orphan girls. It was donated by its owners to the Sociedad de Beneficencia de Buenos Aires (1911) and later, it passed to the orbit of the National State (1946) to the Fundación de Ayuda Social María Eva Duarte de Perón and then under the direction of the National Ministry of Social Development. In 1997, the Unzué was declared a national historic monument; however, several years of abandonment of the building made necessary a series of political actions for its restoration.

Figure 1

Former Saturnino Unzué Institute

Note. Photographs taken by the authors (2022).

The MAR Museum of Contemporary Art (Figure 2) was inaugurated at the end of 2013; it is the product of a national competition for preliminary projects (2009) with the aim of providing the city of Mar del Plata with an art museum on a provincial scale. For the realization of this project, the Ministry of Infrastructure of the Province of Buenos Aires took several steps as promoter of the new cultural initiative.

Figure 2

Museum of Contemporary Art MAR

Note. Photographs taken by the authors (2022).

The Casa sobre el ArroyoMuseum (Figure 3) is a work declared of patrimonial interest at the municipal, provincial and national levels, being a paradigmatic work of the modern movement with international recognition. Although it was built between 1943-1945 for residential use, with the passing of time it was acquired -through a long process of negotiations- by the Municipality of General Pueyrredon with the purpose of becoming a museum.

Figure 3

Casa sobre el Arroyo Museum

Note. Photographs taken by the authors (2022).

As part of the dynamics of the research project, it was possible to develop -through the analysis of cases related to the field of culture- a comparative and integrative study of public management models. In this sense, the research project made it possible to investigate how the works were socially appropriated in different historical contexts, both for their heritage value and for their value as a cultural asset. On the other hand, the review of legislation (by establishing a timeline) made it possible to analyze the linkages between the different levels of the State and, in some cases, the absence of actions because they

were not part of the administrative and/or political project. In this sense, although the three works are located in the local jurisdiction, the municipality has not always been involved in the decision making process regarding the recovery, execution and/or intervention in the properties.

The research approached the objects of the regulations that initiated the management processes that allowed direct or indirect interventions on the tangible and intangible assets of the cultural projects. In this sense, we have shown that, both in the local and national cases, several actions took place prior to the acquisition of the House on the Stream and the patrimonial intervention of the former Saturnino Unzué Institute. In the first case, the participation of the Mar del Plata community, as well as organizations related to architecture and heritage, were the architects of the social pressure for the recovery of the house. In the case of the Unzué Institute, the National Ministry of Social Development, through negotiations with the School of Architecture, Urban Planning and Design, signed a contract for the transfer of services that allowed for the preparation of the technical documentation for the subsequent bidding process for the heritage intervention works. Meanwhile, the physical realization of the MAR Museum was the result of a national competition for preliminary projects for which the provincial government allocated a budget item.

The analysis of interinstitutional and intergovernmental articulation necessarily entails a discussion of the political and institutional dynamics that sustain it, where we can establish which variables are shaped by the rules of the game of power distribution among the political and social actors involved.

The decisions of local, provincial and national governments generated public policies that were reflected in the development of legal instruments such as national, provincial and local declarations, laws and regulations, as well as in concrete actions: expropriations, development of architectural intervention projects, calls for bids and enhancement of the materiality -of the real estate- and of the functionality -giving new functions- to the objects of study.

From the analysis of the different public policies, we established that they were of a substantive nature for the execution and/or recovery of the works addressed. Likewise, there is evidence of procedural policies related to different mechanisms for complying with the objective proposed by the State that were determined for each case study. On the other hand, material policies were also implemented that provided tangible advantages in the reference works. Finally, symbolic policies related to property declarations were proposed.

Discussion and conclusions

Public policies as strategic actions that the State designs and manages must be materialized in a territory, in order to satisfy the demands of a society. The lack of coordination between the different levels or jurisdictions of the State leads to inefficiency in its implementation.

The study of the processes that lead to the management and/or materialization of public policies allows the analysis of a wide range of variables that determine and articulate how the good or service that the policy promotes reaches the most effective way possible to the end for which it was designed.

In this complex scenario, many aspects of policy design are - or must be - modified during implementation, making it necessary for research groups to analyze the entire process in its different phases, in order to establish the emerging dynamics and the variables that determine the success - or otherwise - of the policies implemented.

In this sense, the analysis of the regulatory frameworks has allowed us to understand the way in which they have been developed, their evolution over time, the processes of political commitment for their implementation, as well as their levels of scope and response to social demand. The objective of the articulation between the different levels of the State is to achieve greater coherence and impact of the policies designed, which, due to the lack of comprehensiveness and convergence of the various interventions, is not always achieved, duplicating efforts and resources.

It is important to highlight that the work developed, as a research instance, has also allowed progress to be made in the training of human resources through the incorporation of scholarship students. Likewise, the work establishes the basis for future lines of research by encouraging students, scholarship holders and trained researchers that make up the work team to investigate the management and articulation processes in the different jurisdictions of the State, in relation to heritage assets.

This document has sought to socialize part of the analysis of the emerging processes of cross-cutting public policies between jurisdictions, based on an understanding of the integrality of the territory and the social subject that accesses the agenda of public policies in culture. The theoretical relevance of the research allows us to contribute new knowledge from an interdisciplinary approach to the field of culture.

References

Cicalese, G. and Pereyra, S. (2016). *The preparation of a research project in social sciences and humanities: recommendations for its writing* (1st Ed.). National University of Mar del Plata (UNMdP).

Denzin, N. & Lincoln, Y. (2017). *The art and practice of interpretation, evaluation and presentation*. Gedisa Editorial.

Delgado Godoy, L. (2009). *Public policies. The public policy cycle. Types of public policies. Efficiency, legality and control. Management indicators.* Junta de Comunidades de Castilla-La Mancha. Department of Public Administration. School of Regional Administration. http://pagina.jccm.es/ear/descarga/A2T3.pdf

Escudero Macluf, J., Delfín Beltrán, A. and Gutiérrez González, L. (2008). The case study as a research strategy in the social sciences. *Administrative Science Journal*, *I*, 10. https://www.uv.mx/iiesca/files/2012/12/estudio2008-1.pdf

Oszlak, O. and O'Donnell, G. (1981). *State and state policies in Latin America: towards a research strategy*. Center for the Study of State and Society (CEDES).

Perez Antrakidis, P. and Romero, L. (2022). Interjurisdictional public policies. The case of the Casa sobre el Arroyo, Mar del Plata-Argentina, (2007-2015). *Cultures. Revista de gestión cultural*, 9 (2), 1-23. https://doi.org/10.4995/cs.2022.18237

Ruiz López, D. and Cadénas Ayala, C. (2005). what is a public policy? *IUS Revista Jurídica Universidad Latina de América*, *V*, (18). https://ti.unla.edu.mx/iusunla18/

Yin, R. K. (1994). *Case study research Design and Methods*. U.S.A. Sage.

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:
Gómez Bravo, J. L., Cruz Ramales, S., Rosado García, M. O., Tzompantzi Sánchez, A., & de los Santos Bañuelos, G. (2023). Modelación de la cinética de reacción para la producción de polihidroxialcanoatos microbianos mediante Bacillus megaterium. *Project, Design and Management,* número monográfico, 89-105. 10.35992/pdm.mo2023.1886.

MODELING OF REACTION KINETICS FOR THE PRODUCTION OF MICROBIAL POLYHYDROXYALKANOATES BY BACILLUS MEGATERIUM

José Luis Gómez Bravo
Technological University of Puebla (Mexico)
jose.gomez@utpuebla.com.mx - https://orcid.org/0000-0002-7601-2230
Silvia Cruz Ramales
Technological University of Puebla (Mexico)
silvia.cruz@utpuebla.com.mx -
María Oneida Rosado García
Technological University of Puebla (Mexico)
oneida.rosado@utpuebla.com.mx - https://orcid.org/0009-0001-1774-7720
Alejandro Tzompantzi Sánchez
Technological University of Puebla (Mexico)
alejandro.tzompantzi@utpuebla.com.mx - https://orcid.org/0009-0009-8994-5118
Germán de los Santos Bañuelos
Technological University of Puebla (Mexico)
german.delossantos@utpuebla.com.mx· https ://orcid.org/0009-0005-3028-7027

Summary. The production of poly(3-hydroxybutyrate) PHA by *Bacillus. megaterium* depends exclusively on the concentration of the carbon source (glucose), so it is proposed to use mathematical simulation models for the production of poly(3-hydroxybutyrate) PHA mathematical simulation models are proposed for the kinetics the kinetics applied in the production of microbial polyhydroxyalkanoates. Bacteria can be isolated from California redworm humus, and a logistic model including an inhibition factor and a constant associated with cell maintenance is used for biomass growth. In the kinetics of product formation, the Leudeking-Piret model is proposed, where the product formation coefficient depends on cell growth and the constant associated with cell maintenance, both of which are determined by the fermentation pH, and correspond to associated and non-associated growth, respectively. The model for substrate consumption considers that cells metabolize substrate for growth, product synthesis and energy generation, as well as for internal pH control activities and exchange of cellular components. Kinetic equations are proposed to estimate experimental results of this case study based on the logistic, Leudeking-Piret and substrate consumption models, to determine the values of biomass and product yields, depending on the substrate used in the stoichiometry of PHA production. The next stage involves the application of UV-Vis spectrophotometry to estimate cell growth in Colony Forming Units (CFU) and its comparison with the McFarland scale to equivalently quantify the number of bacterial cells.

Key words: Kinetic models, Bacillus. megaterium, biopolymer.

MODELACIÓN DE LA CINÉTICA DE REACCIÓN PARA LA PRODUCCIÓN DE POLIHIDROXIALCANOATOS MICROBIANOS MEDIANTE BACILLUS MEGATERIUM

Resumen. La producción de poli-(3-hidroxibutirato) PHA por *Bacillus. megaterium* depende exclusivamente de la concentración de la fuente de carbono (glucosa), por lo que se propone utilizar modelos matemáticos de simulación para la cinética aplicada en la producción de polihidroxialcanoatos microbianos. Las bacterias pueden aislarse del humus de la lombriz roja californiana, y para el crecimiento de biomasa se utiliza un modelo logístico que incluye un factor de inhibición y una constante asociada al mantenimiento celular. En la cinética de formación de producto se propone el modelo de Leudeking-Piret, donde el coeficiente de formación del producto depende del crecimiento celular y la constante asociada al mantenimiento celular, ambas están determinadas por el pH de la fermentación, y corresponden al crecimiento asociado y no asociado respectivamente. El modelo para consumo de sustrato considera que las células lo metabolizan para crecimiento, síntesis de producto y generación de energía, así como para actividades de control de pH interno e intercambio de componentes celulares. Se plantea ecuaciones de cinética para estimar resultados experimentales de este caso de estudio basadas en los modelos logístico, de Leudeking-Piret y de consumo de sustrato, para determinar los valores de los rendimientos de biomasa y de producto, en función al sustrato utilizado en la estequiometria de la producción de PHA. La siguiente etapa contempla la aplicación de la espectrofotometría UV-Vis para estimar el crecimiento celular en Unidades Formadoras de Colonias (UFC) y su comparación con la escala de McFarland para cuantificar de forma equivalente el número de células bacterianas.

Palabras clave: Modelos cinéticos, Bacillus. megaterium, biopolímero.

Introduction

Animals and plants possess reserve substances of different chemical nature that provide them with matter and energy for the realization of numerous functions, this type of reserves also exist in microorganisms and provide them endogenously with energy and carbon for specific processes such as the maintenance of the internal pH, osmotic regulation and sporulation (Anderson, 1990; Dawes, 1973). One form of intracellular accumulation of reserve substances among many bacterial genera of the most diverse types is the formation of polymers composed of hydroxy acid units: Polyhydroxyalkanoates (PHA's). In most bacterial species the PHA's are located in intracellular granules that can be visualized under the light microscope by staining with the specific dyes Sudan Black (Smibert, 1981) and Nile Blue (Ostle, 1982).

The *Bacillus megaterium* is a Gram-positive bacillus-like bacterium, mainly aerobic in metabolism, which forms spores and is found in a wide variety of habitats, reaching 1.5 to 3 μm in diameter and up to 5 μm in length (Holt, 1994) it is one of the largest known bacteria. Its cells usually occur in pairs or chains, it grows at temperatures between 3°C and 45°C, with an optimum around 30°C, in some isolates from an Antarctic hydrothermal lake they grow at temperatures of 63°C.

It is considered an endophyte (lives as an endosymbiont of plants without causing damage) and is a potential agent for plant disease control. It has been shown that certain strains can be used to fix nitrogen. It produces the penicillin amidase enzyme used to produce synthetic penicillin, several amylases used in the baking industry and glucose dehydrogenase (enzyme used in blood glucose testing). In addition, it is used for the production of pyruvate , vitamin$_{B12}$, drugs with fungicidal and antiviral properties , etc.. It produces enzymes to modify corticosteroids and several amino acid dehydrogenases. It produces poly-γ-glutamic acid, the accumulation of the polymer increases considerably in saline environments (2-10% NaCl), in which the polymer is largely formed by L-glutamate (the content of the L-isomer is up to 95%).

At least one strain of *B. megaterium* can be considered halophilic, as it grows in concentrations of up to 15% NaCl. This species can be found in soils, seawater and its sediments, rice husks, dried foods and milk, throughout all latitudes of the planet.

This bacterium is very versatile because, in addition to its arsenal of enzymes usual for all Gram-positive microorganisms, it possesses other types of enzymes uncommon for its genus; this gives it great metabolic plasticity, which translates into a remarkable ability to survive in different environments and ecological niches (Rao, 2019). Its ability to metabolize different compounds rivals that of the genus Pseudomonas. (Vary, 1992). The most important reserve compound in this species is poly(3-hydroxybutyrate) (PHB), which accumulates under limiting conditions of nitrogen, phosphates, sulfur or potassium (Slepecky, 1961).

Worldwide, more than 30% of waste corresponds to petroleum-derived plastics that generate toxins and are not biodegradable. Polyhydroxyalkanoates (PHA's) are biopolymers that represent a solution to the environmental pollution caused by synthetic plastics, since they come from a biological organic synthesis and therefore their degradation is fast, it can be in a moderate time of up to 9 months (Bailey, 1986; Verlinden, 2007).

In this proposal it is assumed that PHB production by *B. megaterium* depends exclusively on glucose concentration. Since the specific growth rate variable depends on the biomass of the microorganism involved, it is essential to evaluate its reproduction rate for stoichiometric product generation.

The glucose fermentation system in microbial metabolism is integrated by three different reactions that occur simultaneously, for this work we propose a kinetic model for substrate consumption (glucose), one more for biomass growth (*Bacillus megaterium*bacterial cells) and finally another one for PHA's production. The feasibility of biopolymer synthesis under controlled parameters such as pH, dissolved oxygen and temperature is theoretically estimated. The objective of the present work is to propose three mathematical simulation models for reaction kinetics.

The growth of cells is obtained by the product of interactions between biochemical reactions and the phenomena of matter and energy transfer through various stages comprised in systems. The mixture of new and old cells undergoes constant changes during the development process represented by a growth curve, while adapting to an environment with permanent variations in physical and chemical conditions. Because of the difficulty in accurately modeling growth kinetics, some assumptions must be made to obtain simple models for the design, operation and prediction of fermentation process behavior. The unstructured model is the simplest and most commonly employed, and is based on the following implications: the cells can be represented by a single component such as cell number, cell mass or the concentration of proteins, deoxyribonucleic acid (DNA) or ribonucleic acid (RNA); the bacterial population has a uniform distribution; the cell suspension is homogeneous; the heterogeneous nature of the cells is not considered and the cell concentration is expressed as mass of cells on a dry basis per unit volume; the medium is formulated so that only one component is rate limiting; the other components are present in sufficiently high concentrations to avoid the effect of small changes on the reaction rate; the biological reactor is controlled to ensure a constant level of suitable environmental conditions (González, 2013).

Microbial kinetics is analyzed in relation to the formulation of unstructured growth models. The simplest models of bacterial growth, also called unstructured models, are stated in terms of abstract units of life, i.e., they are oriented to the term biomass, leaving aside the organelles that make up the cells that in turn make up the biomass; in practical terms, the microbial population is considered as a homogeneous unit. Although these models propose simple equations by virtue of the fact that the microorganism is estimated as an elementary

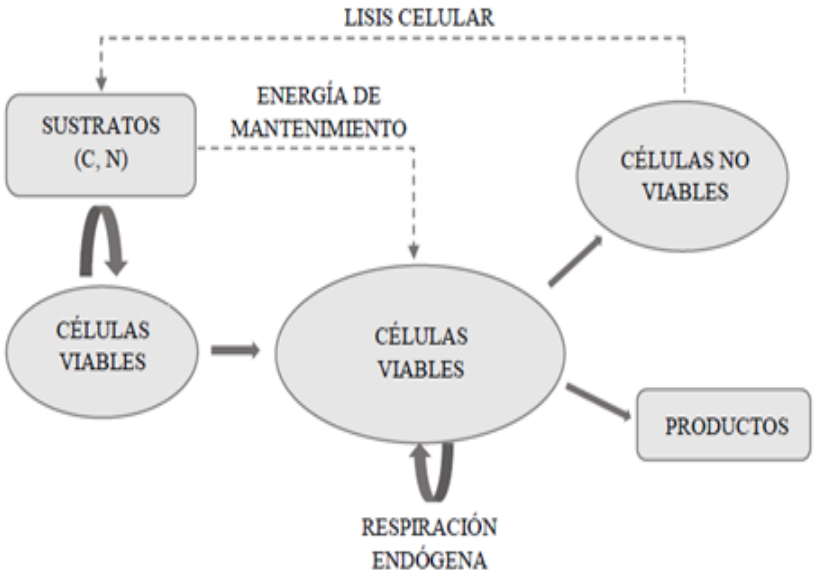
reactant species, they are valid for applications with technological objectives.

These types of models respond to the representation shown in Figure 1, which represents the consumption of substrate by microorganisms, both for their reproduction and for the generation of products, and at the same time explains the concepts of endogenous respiration and maintenance energy (Kim D., 2007).

Unstructured models consider the parameters involved in the microbial kinetic pathway, such as biomass growth, substrate consumption and product formation.

Figure 1

Simplified feedback for the unstructured model



Note. Taken from (Kim D., 2007)

Method

Unstructured models are adequate when microorganisms have a cellular composition close to steady state; when there are changes in cellular composition, they provide in most cases a poor approximation to reality. If unstructured models are not able to reflect the influence of certain variables such as the composition of the medium, changes in the internal structure of the microorganism must be considered and in very complex cases only these will be able to explain the evolution of the culture.

For the study of the kinetic behavior of biomass, substrate and product in the production of biopolymers, we considered the case study reported in Mathematical modeling and optimization of the production process of polyhydroxyalkanoates using the bacterium *Burkholderia cepacia* B27 from fatty acids, where tests were carried out for 77 hours of reaction (Suriyamongkol P., 2007)where tests were carried out during 77 hours of reaction.

Table 1 shows the concentration data for biomass (X), sucrose (S) and product (P)obtained during the kinetic monitoring of this case.

Table 1

Biomass (X), sucrose (S) and product (P) concentrations

t (h)	Concentration X (g/L)	Concentration S (g/L)	Concentration P (g/L)
0	1.46	20	0.22
6	1.83	19.56	0.58
11	3.19	17.94	1.47
23	5.7	14.94	4.34
30	7.17	13.19	6.02
35	11.23	8.34	8.68
47	13.54	5.59	13.08
53	15.91	2.75	14.88
59	15.08	3.74	14.19
71	15.09	3.73	14.32
77	15.4	3.36	13.2

Note. Taken from (Khalseh, 2016)

The most commonly used empirical formula for the organic fraction of cells is$C_5H_7O_2N$. The formulation$C_{600}H_{87}O_{23}N_{12}P$can be used when phosphorus is also considered. Both formulations are approximations and may vary.

To support microbial growth in biological systems, appropriate nutrients must be available. Prokaryotic cells are composed of approximately 80% water and 20% dry material, of the latter 90% is organic and 10% is inorganic.

Considering that the composition of prokaryotic cells consists of approximately 80% water and 20% dry material, of which 90% is organic and 10% is inorganic, the formula C10H21O3N2 is obtained (Almudena, 1999)the formula $C_{10}H_{21}O_3N_2$is obtained; for biomass, this is shown in Table 2.

Table 2

Typical percentage composition of a bacterium

Cellular elements	Dry weight percentage (%)
Carbon	50
Oxygen	22
Nitrogen	12
Hydrogen	9
Phosphorus	2
Sulfur	1
Potassium	1
Sodium	1
Calcium	0.5
Magnesium	0.5
Chlorine	0.5
Fierro	0.2
Other trace elements	0.3

Note. Taken from (Metcalf & Eddy, 2005).

Then for one mole of substrate and in the particular case glucose($C_6H_{12}O_6$), the stoichiometric reaction involved in the production of the PHB biomonomer as well as that of polymerization are shown in Equations 1 and 2 respectively.

$$C_6H_{12}O_6 + \tfrac{2}{3}NH_3 + \tfrac{5}{12}O_2 \longrightarrow \tfrac{1}{3}C_{10}H_{21}O_3N_2 + \tfrac{1}{3}C_4H_6O_2 + \tfrac{4}{3}CO_2 + \tfrac{5}{2}H_2O + \Delta H_r \quad (1)$$

$$nC_4H_6O_2 \rightarrow (C_4H_6O_2)_n \quad (2)$$

The generation of the PHB biopolymer $(C_4H_6O_2)_n$ depends on the growth or development of the biomass ($C_{10}H_{21}O_3N_2$), which in turn is a function of the substrate concentration ($C_6H_{12}O_6$), as shown in equation 3.

$$C_6H_{12}O_6 + aNH_3 + b\,O_2 \longrightarrow Y_{X/S}\,C_{10}H_{21}O_3N_2 + Y_{P/S}\,C_4H_6O_2 + Y_{CO_2/S}\,CO_2 + wH_2O + \Delta H_r \quad (3)$$

where:

a = Mass ratio of the amount of nitrogen source consumed/substrate consumed.

b = Mass mass ratio of the amount of oxygen consumed/substrate consumed.

$Y_{X/S}$ = Coefficient mass coefficient of biomass yield/substrate consumed.

$Y_{P/S}$ = Coefficient mass coefficient of product/substrate yield consumed.

$Y_{CO_2/S}$ = Mass ratio of the amount of$_{CO2}$ released/substrate consumed.

w = Mass coefficient of the amount of water produced/substrate consumed.

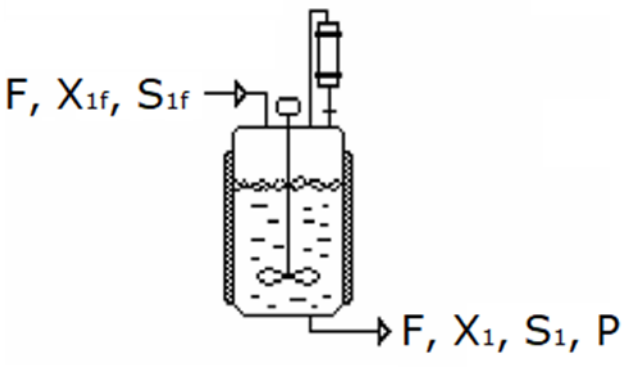
The coefficient $Y_{X/S}$ is a function of the initial amount of substrate available, as well as the nutrients and operating conditions or environmental parameters.

The coefficient $Y_{P/S}$ is a function of the amount of biomass generated and the capacity of the bacteria for the production and accumulation of the biopolymer, which depends proportionally on the degree of stress to which the bacteria can be subjected, due to the change in the concentration of the nutrient selected as limiting reagent, as long as the bacteria are not in the endogenous phase.

The mathematical model proposed to describe the process takes into account an input and an output in the bioreactor, behaving as a continuous stirring system (CSTR). The process scheme, as well as the nomenclature of the streams, is shown in Figure 2.

Figure 2

Schematic of a CSTR for a fermentative process



Note. Taken from (Khalseh, 2016).

The reaction carried out in the reactor can be expressed in the form 4:

$$S + X \rightarrow P + X \qquad (4)$$

where:
S=Substrate.
X=Biomass.
P=Product concentration.

The overall mass balance for the system in Figure 2 is given by 5 (Khalseh, 2016):

$$Entrada - Salida + Generación = Acumulación \qquad (5)$$

Consider the system presented in Figure 2 where there is only one input and one output.

For the process in a batch reactor, it must be considered that there are no inputs or outputs, therefore, the behavior for the constant reaction volume in the balance for biomass takes the form of equation 6.

$$Generación = Acumulación \qquad (6)$$

Fermentative production of PHA is normally operated as a two-stage fed-batch process (Metcalf & Eddy, 2005). An initial growth phase in a nutritionally enriched medium produces sufficient biomass, followed by a product formation phase in a nitrogen-poor medium. Single fed-batch fermentations that are nitrogen-limited lead to low amounts of polymer, because there is insufficient biomass accumulation (Katırcıoğlu H., 2003). PHA production in pure cultures is limited by an external nutrient. When cells are exposed to a medium with very low amounts of nutrients for a long time, the bacteria are physiologically altered (Daigger, 1982). The sudden increase in carbon substrate concentrations causes the cell to change its physiology again. As PHA synthesis requires less adaptation than growth, the culture begins to produce polymer, this type of fermentation is known as endogenous decay. (Días J., 2005; Lemos P., 2006).

The kinetics of microbial growth, substrate consumption and product formation are routinely formulated in terms of equations that lead to coupling between the associated cups as for example in the case of the equations:

$$\frac{dX}{dt} = f(X\ P, S) \qquad (7)$$

$$\frac{dP}{dt} = g(X\ P, S) \qquad (8)$$

$$\frac{dS}{dt} = h(X\ P, S) \qquad (9)$$

Consequently, it is often not possible to find analytical solutions to these equations so numerical solution techniques are often usefully employed.

Batch microbial growth is characterized by two regions, the exponential growth region shown in equation 10 and the stationary growth region $\frac{dX}{dt} = 0$. It is not uncommon for the transition region between these two kinetic regions of substrate-dependent growth rates to occupy 10% to 20% or less of the total fermentation time. Consequently, for many batch fermentations, a simpler approach is available as an equation that takes a self-contained growth form, i.e, $\frac{dX}{dt} = f'(X)$.

A *logistic* model is used for biomass growth, so the equation that adequately describes the biomass growth rate is shown in the Monod equation (10).

$$\frac{dX}{dt} = \mu X \qquad (10)$$

where:

$$\mu = k\left(1 - \frac{X}{X_{máx}}\right) \qquad (11)$$

$\frac{dX}{dt}$ = Cell growth rate (M/L^3t).
μ = Specific growth rate (t^{-1}).

$k =$ Inhibition factor (t^{-1}).
$X =$ Biomass concentration (M/L^3).
$X_{máx} = \frac{1}{\beta} =$ Maximum biomass concentration (M/L^3).

Combining 10 and 11 gives12 , known as the Riccati equation

$$\frac{dX}{dt} = kX(1 - \beta X) \qquad (12)$$

Product formation occurs throughout the cell growth phase and is expressed in equation 13.

$$\frac{dP}{dt} = \alpha \frac{dX}{dt} + \beta X \qquad (13)$$

where:

$\alpha =$ Product formation coefficient associated with cell growth.

$\beta =$ Constant associated with cell maintenance (L^3/M).

The rate of substrate consumption is given by 14.

$$\frac{dS}{dt} = -\frac{1}{Y_{X/S}} \frac{dX}{dt} - \frac{1}{Y_{P/S}} \frac{dP}{dt} - k_e X \qquad (14)$$

where:

Yx/s= actual biomass yield with respect to substrate.

Yp/s= Actual product yield with respect to the substrate.

ke=Maintenance coefficient in [gS / gX h].

The logistic model is used for biomass growth X, which is presented in equation 12. This model includes an inhibition factor k [$^{h-1}$] and a constant associated with cell maintenance β [g P / g X h]. The resolution of the model (equation 15) is used to find the values of the constants in the velocity expressions.

$$ln\left(\frac{X/X_0}{1-X/X_s}\right) = kt - ln\left(\frac{X_s - X_0}{X_0}\right) \qquad (15)$$

where:

Xs = Biomass concentration in stationary phase obtained from a plot of X vs t.

For the kinetics of P product formation, the Leudeking-Piret model is proposed (equation 13), where the constants ∝ y β are determined by the fermentation pH, and correspond to the associated and non-associated growth of this parameter, respectively. By integrating 13, 16 is obtained.

$$P - P_0 = \frac{1}{k} ln\left(1 - \beta X_0 (1 - e^{kt})\right) + \alpha (X - X_0) \qquad (16)$$

Substrate consumption S (equation 14), considers that cells consume substrate for growth, product synthesis and energy generation, internal pH control activities and exchange of cellular components. Integrating 14 yields 17.

$$S - S_0 = \frac{\eta}{k\beta} ln\left(\frac{1}{1 - \beta X_0 (1 - e^{kt})}\right) - \delta (X - X_0) \qquad (17)$$

being:

$$\delta = \frac{1}{Y_{X/S}} + \frac{\alpha}{Y_{P/S}} \qquad (18)$$

$$\eta = \frac{\beta}{Y_{P/S}} + k_e \qquad (19)$$

Equations 18 and 19 are expressed in units of (g S/ g X) and (g S / g X.h) respectively.

The culture of *B. megaterium* bacteria comes from worm humus from the isolation of colonies in nutrient agar, an inoculum of 0.5 g/L is prepared, which is approximately equivalent to 1.0 x^{108} bacteria/mL, and the concentration of colony forming units (CFU) is confirmed on the scale of the Mac Farland Nephelometer and the UV-visible Spectrophotometer (McFarland, 1907)the concentration of colony forming units (CFU) is confirmed on the Mac Farland Nephelometer scale and in the UV-visible Spectrophotometer.

Results

It is assumed that PHA production by *Bacillus megaterium* depends exclusively on glucose concentration. Once the rate equations for biomass formation, product and substrate consumption were established, we proceeded to solve them analytically and graphically, taking as a basis the experimental values reported in the work by (Méndez, 2016). The results of equations 12, 13 and 14 are shown in Table 3 and presented graphically in Figures 3, 4 and 5:

Table 3

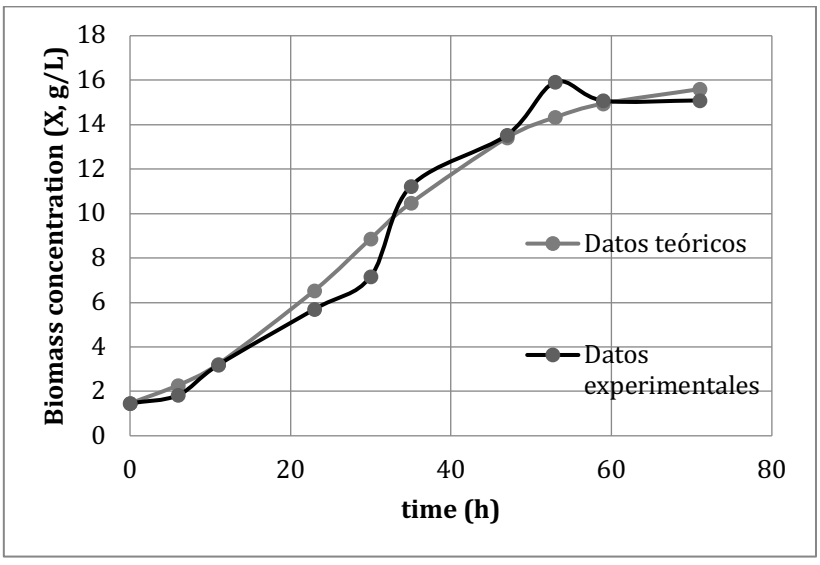
Calculated values for the parameters of the kinetic equations

Parameter	Definition	Value	Units
k	Inhibition factor	0.084	h^{-1}
α	Coefficient of product formation associated with cell growth	1.033	g P / g X
β	Constant associated with cell maintenance	0.0625	g P / g X · h
δ	Parameter associated with biomass and product formation	0.667	g S / g X
η	Parameter associated with cell maintenance	0.014	g S / g X · h

Figure 3 shows a comparison of experimental and theoretical data of the model proposed in equation 12, for the growth kinetics of biomass X.

Figure 3

Biomass growth kinetics X(g/L) vs time(h)



Note. Own elaboration (2022)

Figure 4 shows graphically the experimental and theoretical data of the model proposed in equation 13, for the growth rate of product P.

Figure 4

Kinetics of product concentration P(g/L) vs time(h)

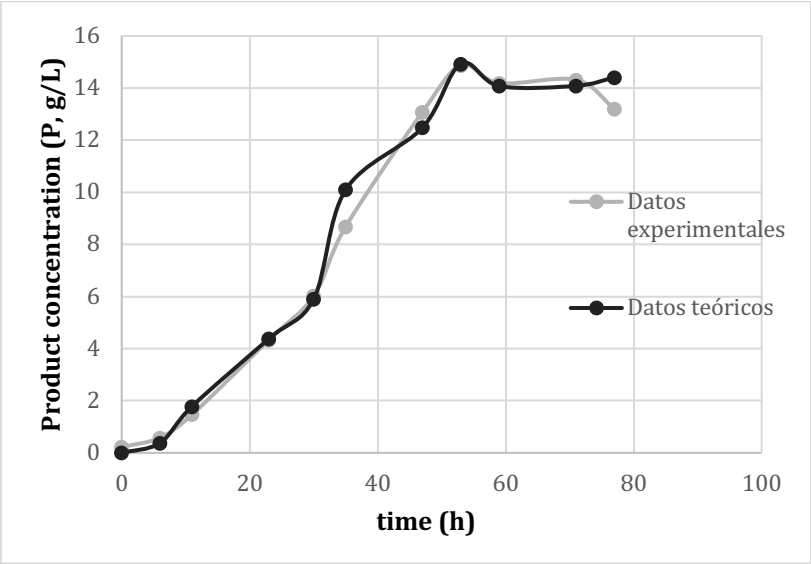
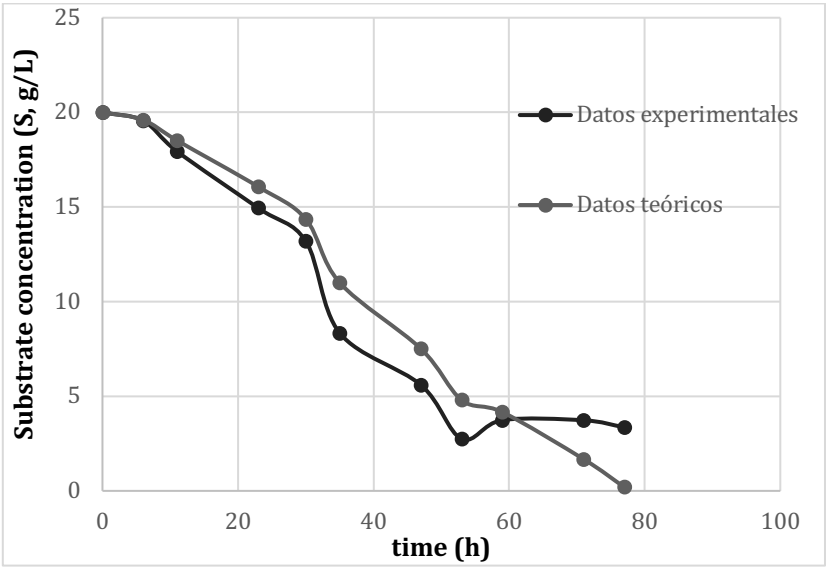


Figure 5 shows graphically the experimental and theoretical data of the model proposed in equation 14, for the rate of substrate consumption S.

Figure 5

Kinetics of substrate consumption S (g/L) vs time (h)



To validate the simulated values in the proposed solution models, (equations 12, 13 and 14) an Analysis of Variance (ANDEVA) was used considering a confidence level of 95%; in the case of biomass (X), product growth (P) and for substrate consumption (S), it is found that the experimental values $_{F0}$ *=0.0807*, $_{F0}$ *=0.09450*,$_{F0}$=0.0714 respectively, which are lower than the$_{Fcritical}$F= 4.4138 in all cases, indicating that the experimental and theoretical data are statistically equal.

Discussion and conclusions

In the contemporary world, the production of microbial biopolymers is a booming alternative, being this a biodegradable product in the final stage of its life cycle that reduces the impact on the environment, although some strains producing bioplastics are pathogenic to humans, others do not present this disadvantage to carry out research work of this profile. In the search for bacteria that do not transmit diseases, but produce biopolymers, the presence of *Bacillus megaterium*is favored, since it is a microorganism capable of producing polyhydroxybutyrate (PHB) from fruit residues, besides being a bacterium widely distributed in soil, and also easily recoverable in humus of red Californian earthworms fed with fruit residues.

The kinetic models developed as a function of time allow the evaluation of the biochemical process of the microorganism, the production of metabolites and the evolution of energy, and its dependence on controllable factors such as pH, temperature, concentration, etc.

The basis for this work is the study of the growth kinetics of the bacterium *Burkholderia cepacia,* which made it possible to identify the performance and productivity indicators for biomass production based on mathematical models (equations 12, 13 and 14); with this information, the kinetic parameters of the fermentation process were obtained: biomass growth, product generation and substrate consumption.

In the modeling of biomass growth X , the *logistic* model of the unstructured type is used, expressed in terms of abstract units of life: microbial population or biomass, completely ignoring the internal structure of the cells that compose the biomass, since they consider the population as a homogeneously distributed unit. Although unstructured models represent a great simplification of the real problem, they are useful for technological purposes, since they provide simple equations that make physical sense, in which the microorganism is treated as a simple reactant species. The most complicated scheme to which this type of models could respond, considers the consumption of substrates by the cells, both to grow and to generate products, as well as the concepts of endogenous respiration and maintenance energy, this is fulfilled for the objective of this work that proposes to quantify in a theoretical way the amount of biopolymer produced, and in a subsequent stage will be tested with the bacterium *B. megaterium*.

In the case of biomass growth X , the *logistic*model is used, which is presented in equation 12. This model includes an inhibition factor k and a constant associated with cell growth β. The solution of the model presented in Equation 15 is used to find the values of the constants in the velocity expressions associated with Figure 3, which shows the kinetics of biomass formation with respect to time.

For *P-product* formation, the Leudeking-Piret model shown in Equation 13 is proposed, where the constants α and β are determined by the fermentation pH, and correspond to associated and non-associated growth, respectively. This implies that the first term corresponds to the proportional production of the metabolite with respect to cell growth, while the second term shows how all microorganisms produce a constant proportion of product regardless of the growth phase (Reynolds, 1996) The kinetic monitoring of the biomass allows observing an exponential growth phase of a maximum of 35 hours of reaction and a stationary phase close to 72 hours. Equation 16 presents the analytical solution of Equation 13, associated with Figure 4, where the kinetics of product formation is shown with respect to time.

The substrate consumption S presented in equation 14 takes into account that cells metabolize the carbon source for growth, product synthesis and generation of energy and new

cellular components. The solution of equation 14 is shown in equation 17, which is represented in Figure 5, where the kinetics of substrate consumption is shown with respect to time.

The experimental data and the theoretical values shown in the three cases: biomass development, product formation and substrate consumption, were statistically equal according to an analysis of variance, which implies that the reliability is acceptable for its application in the calculation of bacterial biological reaction kinetics for the formation of products of industrial interest as substitutes for synthetic plastics.

According to the analysis carried out, the proposed models prove to be effective to establish the evolution of a process where microbiological organisms intervene in the degradation of a substrate with the consequent formation of a degradable biopolymer, therefore, the next stage is the experimental test of the procedure of biotransformation of nutrients to PHA's using a biological reactor type CSTR with a volumetric capacity of 5 liters operated in batches at 80% of its capacity, with a glucose solution of concentration 20 g/l and a bacterial suspension of *Bacillus megaterium* isolated from earthworm humus equivalent to the concentration of scale 0.5 of Mac Farland (McFarland, 1907).

Knowledge of how the cell population expands is useful for the design of methods to control microbial growth. A relevant point is the increase in biomass and the generation of the products that can be obtained. The biological processes carried out in this project are mainly chemical, involving microbiological agents. Thus, such a bioprocess can be represented by a stoichiometric chemical reaction. The growth of microorganisms is related to the number of viable cells present, the amount of substrate and limiting nutrients, as well as other environmental factors such as temperature, humidity, pH, dissolved oxygen, etc. In the cell growth curve four phases can be distinguished, usually referred to as: adaptation, exponential growth, stationary, logarithmic or endogenous death (Méndez, 2016).

The quantification of microorganisms is a fundamental factor in projects involving biological processes, the most commonly used technique is that which considers the plate count of bacteria present in a unit volume by serial dilutions from an initial sample and then seeding a standard amount with a sterile glass support on a plate containing suitable culture medium, and incubating until visible colonies are obtained for counting, a disadvantage of the method is that it leads to a high consumption of nutrients, substrate and reagents, in addition to the time invested. On the other hand, there are visual and optical methods that allow quantifying the number of previously isolated and identified cells in less time, such is the case of the optical method of the McFarland scale, where the bacterial suspensions are compared visually with the standards until the most similar in turbidity is found and the number of cells according to each standard [colony forming unit (CFU)/mL] is related to the number of cells according to each standard [colony forming unit (CFU)/mL].

In addition, a methodology is proposed to compare the inoculum concentration of *Bacillus megaterium*bacteria, through the correlation between spectrophotometric and turbidimetric methods, using the solutions of the test tubes of the concentrations of the McFarland scale. A series of ten tubes are prepared with a fine precipitate solution of barium sulfate obtained by mixing barium chloride dihydrate of concentration 0.048M with 0.18M sodium sulfate, in different proportions, which resembles bacterial suspensions that are instrumentally compared with the standards to correlate with the number of cells, using a Varian UV-vis double beam spectrophotometer model Cary 300 Scan at a wavelength of 600 nanometers**(nm**).

In conclusion, biomass production in a biological reaction tends to be exponential up to a certain time, which depends on the amount of substrate, types and concentration of nutrients and development parameters. The stoichiometry of the biochemical reaction is proposed to

determine the production of PHB by the optimal metabolic process of the bacterium *Bacillus megaterium*. The proposal proposes the application of mathematical models of reaction kinetics to analyze the PHB formation process, biomass and product yields, from the ideal and theoretical points of view. The calculation of the limiting substrate depends on the selected microorganism and the metabolism that characterizes it. The proposed simulation models can determine the values of real biomass yield with respect to the substrate ($Y_{x/s}$), real product yield with respect to the substrate ($Y_{p/s}$), and stoichiometry for PHA production; they also adequately describe the evolution of the process. It should be noted that with the available information it is only possible to estimate the range of energy for cell maintenance, since there is no exact theoretical or real information available on the cell maintenance coefficient(k_e)

This work explores sustainable biotechnological alternatives for the substitution of synthetic polymers. The proposal offers the advantage of a kinetic model of bacterial growth for the sustainable generation of PHB biopolymer from a waste used as a substrate, in this case fruit peels, to generate a biodegradable product.

Bacillus megaterium bacteria will be isolated from California red earthworm humus(*Eisenia foetida*) fed with fruit residues, which will provide added value to the work, since this condition complies with a sustainable production and consumption model, in which the raw material is focused on the use of residues and is part of the productive cycles with inputs that can be used recurrently and thus minimize the generation of residues. A methodology is also proposed to quantify the concentration of the *Bacillus megaterium* bacteria inoculum for the preparation of the bacterial suspension that will be inoculated into the biological reactor at laboratory scale. To know the cell concentration of the inoculum, UV-vis spectrophotometry is used, this is supported by the data of the correlation percentage coefficients (R^2). This proposal allows calculating the bacterial density at the beginning of the process and also during the sampling intervals to know the progress of the reaction and development of the bacteria with respect to the substrate, nutrients and environmental conditions.

The energy that microorganisms absorb from their environment is transformed into chemical energy which is then converted to perform the chemical work involved in the biosynthesis of cellular organelles, the osmotic work necessary for the transport of materials inside the cell (as happens in the synthesis of PHB), or the mechanical work of contraction or locomotion; as well as in the generation of new cells.

The above corroborates that the biotransformation carried out for the generation of the product depends on the type of metabolism developed by each microorganism, the physical and chemical environmental conditions, the type of substrate and the methodological sequence applied.

The work contributes to create an eco-sustainable environment with a technological approach at the service of people and the well-being of the planet, to recover harmony with nature and common resources, where waste is used to generate environmentally friendly products such as bacterial bioplastics, replacing those that are pollutants such as synthetic plastics derived from petroleum.

References

Metcalf & Eddy. (2005). *Wastewater Treatment Engineering.* (4th Ed.). Mc Graw Hill.

Almudena, A. M., García-Ochoa, S. F., & Santos, V. E. (1999). *Desarrollo de modelos cinético*. Universidad Complutense de Madrid.

Anderson, A. (1990). Occurrence, metabolism, metabolíc role and industrial uses of Bacterial Polyhydroxyalkanoates. *Revista Microbiol, 54*, 451-472.

Bailey, J. E. (1986). *Biochemical Engineering Fundamentals.* (2th Ed.). Mc Graw Hill Inc. .

Daigger, G. & Grady L. (1982). An assessment of the role of physiological adaptation in the transient response of bacterial cultures, *Biotechnology & Applied Microbiology, 24*(6), 1427-1444.

Dawes, E. (1973). The role and regulation of energy reserve polymers in microorganisms. *Adv.Microbiol. Physiol, 14*, 135-266.

Dias, J.M.L., Serafim, L.S., Lemos, P.C., Reis, M.A.M., & Oliveira, R. (2005). Mathematical modelling of a mixed culture cultivation process for the production of polyhydroxybutyrate. *Biotechnol Bioeng, 20*(2), 209-22. https://doi.org/10.1002/bit.20598

González G. Y., Meza C. J.C., Orfil González R.O., & Córdova L. J.A., (2013). Síntesis. *Revista internacional de contaminación ambiental, 29 (1)*, 77-115.

Holt, J. G. (1994). *Bergey's manual of determinative bacteriology.* Lippincott Williams & Wilkins.

Katırcıoğlu H., e. a. (2003). Production of poly-beta-hydroxybutyrate (PHB) and differentiation of putative Bacillus mutant strains by SDS-PAGE of total cell protein. *African J Biotechnol 2*, 147-149.

Khalseh, R. (2016). Evaluation of different kinetics for bioethanol production with emphasis to anlaytical solution of substrate equation. *Theoretical Foundations of Chemical Engineering, 50*(4), 392-397.

Kim D., e. a. (2007). Biosynthesis, modification, and biodegradation of bacterial medium-chain-length polyhydroxyalkanoates. *The Journal of Microbiology*, 87-97.

Lemos P., e. a. (2006). Synthesis of polyhydroxyalkanoates from different short-chain fatty acids by mixed cultures submitted to aerobic dynamic feeding. *Journal of Biotechnology, 122*(2), 226-238.

McFarland, J. (1907). The nephelometer: an instrument for estimating the numbers of bacteria in suspensions used for calculating the opsonic index and for vaccines. *J. Am. Med. Assoc. 49*, 1176-1178.

Méndez, D. (2016). *Modelamiento matemático y optimización del proceso de producción de polihidroxialcanoatos empleando la bacteria Burkholderia cepacia B27 a partir de ácidos grasos.* Universidad Nacional de Colombia.

Narsing Rao, M. P., Dong, Z-Y., Liu, G.H., Xiao, M., & Li, W. L. .(2019). Reclassification of Bacillus aryabhattai Shivaji et al. 2009 as a later heterotypic synonym of Bacillus megaterium de Bary 1884 (Approved Lists 1980). *FEMS Microbiology Lett, 366*(22). https://doi.org/10.1093/femsle/fnz258

Ostle, A. (1982). Ostle A. y HoltNile Blue as a fluorescent stain for poly-B-hydroxybutyrate. *Appl. Env. Microbiol. 44*, 238-24l.

Reynolds, T. (1996). *Unit Operations and Processes in Environmental Engineering.* CENGAGE Learning.

Slepecky, R. (1961). Synthesis and degradation of poly-B-hydroxybutyric acid in connection with sporulation of Bacillus megaterium. *J. Bacteriol, 82*, 37-42.

Smibert, R. (1981). *Manual of methods for general microbiology.* American Society for Microbiology.

Suriyamongkol P., e. a. (2007). Biotechnological approaches for the production of polyhydroxyalkanoates in microorganisms and plants. A review. *National Library of Medicine*, 168-175.

Vary, P. (1992). Development of genetic engineering in Bacillus megaterium. In R.H. Doi & M. McGloughin. *Biology of Bacilli Applications to Industry*. Butterworth-Heinemann.

Verlinden R.A.J., Hill D.J., Kenward M.A., Williams C.D., Radecka I. (2007). Bacterial synthesis of biodegradable polyhydroxyalkanoates. *Journal of Applied Microbiology. 102(6)*, 1437–1449.

PROJECT, DESIGN AND MANAGEMENT

https://www.mlsjournals.com/Project-Design-Management

ISSN: 2683-1597

How to cite this article:
Alfaro Cazares, N. G. (2023). Desarrollo de competencias blandas em estudiantes de Ingeniería: trabajo colaborativo. *Project, Design and Management,* número monográfico, 106-113. 10.35992/pdm.mo2023.1889.

DEVELOPMENT OF SOFT SKILLS IN ENGINEERING STUDENTS: COLLABORATIVE WORK

Neydi Gabriela Alfaro Cazares
Autonomous University of Nuevo Leon (Mexico)
neydi.alfarocr@uanl.edu.mx - http://orcid.org/0000-0002-2618-1634

Summary. This work focuses on the development of soft skills focused on the engineering student, based on the collaborative work model, which is currently important for employers that the graduate is integrated into the work team and can obtain favorable results, for this work a quantitative methodology was used, where a questionnaire was applied that allows to know the social skills possessed by students, the development of the same was on a Likert scale, it was applied through an online platform, it was applied through an online platform, obtaining a sample of 530 undergraduate students in engineering at a university in the northeast of Mexico, then the answers were analyzed, to subsequently obtain as results that the way to integrate is in groups to perform teamwork, as conclusions it is important that students develop during their stay in collaborative work, because this includes effective communication, negotiation, empathy and leadership, which is a skill that is required in the working world.

Keywords: soft skill, student, collaborative work.

DESARROLLO DE COMPETENCIAS BLANDAS EN ESTUDIANTES DE INGENIERÍA: TRABAJO COLABORATIVO

Resumen. El presente trabajo se enfoca en el desarrollo de las competencias blandas centradas en el estudiante de ingeniería, basado en el modelo de trabajo colaborativo, que actualmente es importante para los empleadores que el egresado se integre al equipo de trabajo y pueda obtener resultados favorables, para este trabajo se utilizó una metodología cuantitativa, donde se aplicó un cuestionario que permite conocer las habilidades sociales que poseen los estudiantes, el desarrollo del mismo fue en escala de Likert, se aplicó a través de una plataforma en línea, obteniendo una muestra de 530 estudiantes de licenciatura en ingeniería en una universidad del noreste en México, posteriormente se analizaron las respuestas, para posteriormente obtener como resultados que la forma de integrarse es en grupos para realizar trabajo en equipo, como conclusiones es importante que estudiante desarrolle durante su estancia en el trabajo colaborativo, porque este incluye una comunicación efectiva, negociación, empatía y liderazgo, que es una habilidad que se requiere en el mundo laboral.

Palabras clave: *habilidad blanda, estudiante, trabajo colaborativo.*

Introduction

Currently, most higher education institutions emphasize the need to include the development of both hard and soft competencies in the curriculum, in order to meet the personal, academic and professional demands required by the context in which we live.

Hard competencies are the technical knowledge and experience necessary to perform a job, while soft competencies are interpersonal qualities, social skills and personal attributes of each individual. These refer to a broad group of skills, behaviors and qualities that enable people to function efficiently in their environment, have effective relationships, perform work professionally and achieve the goals they set for themselves (Lippman et al., 2014). Soft skills are considered complementary to hard skills, which are trained in universities, due to their important role in the current context. However, although these are discussed as important, there is a lack of consensus on their characterization and implementation (Yan, et al., 2019).

Higher education institutions are aware that having an adequate level in educational quality and training, not only imply a certain mastery of the contents of a given educational program, but students also have the need to fully develop the necessary competencies and skills to have greater chances of successfully participating in the labor market (Garcia, 2016).

As the industry sector has advanced, it has become vital to incorporate more people with talent, not only technical or cognitive talent that is deployed through hard skills, but also to adequately develop soft skills, as these complement each other. Soft skills have been one of the most important traits and variables determining success in job performance for at least the last decade (Pandey et al., 2022).

Currently, soft skills, also considered as non-cognitive, are more valued by employers than hard skills in the workplace, as it helps in determining that they possess a willingness to work collaboratively, are perseverant and demonstrate leadership in decision making.

Garcia (2018, p.9), mentions that "The National Research Council and the National Academy of Sciences of the United States categorize the 21st century skills into three: cognitive, interpersonal and intrapersonal skills", and that the subject who possesses the three aforementioned skills will be able to develop successfully.

The Organization for Economic Cooperation and Development (OECD) during 2016 included in the test named as The Programme for International Student Assessment of the OECD (PISA) the importance of collaborative work development as a soft skill (OECD, 2016), and three years later established that smaller companies when surveyed externalized that graduates lack soft skills for innovation, therefore, collaborative work and leadership are skills considered of importance for recruiters (OECD, 2019).

Ortega (2016) highlights that the results of a survey applied in some work teams, revealed the absence of collaborative work, therefore highlights the priority that young people develop soft or non-cognitive skills, and these should be generated from an early age, presenting the position that society requires a flexible, proactive and responsible youth with a capacity for critical thinking, who can perform collaborative work and have willingness to solve problems in a committed manner. In a society that is moving towards transformation, soft skills, therefore, are not something that is sought "preferably" to be had, but are as important as cognitive skills, because although these are essential to ensure that the work is done correctly, unless they are combined with people's soft skills, such as the ability to work collaboratively, negotiation and leadership, among others, it is what allows the professional potential of those involved in this transformation to increase.

It is considered that nowadays after the COVID-19 pandemic, the need to develop the capacity for collaborative work has become evident, for example, the capacity for effective communication, collaboration and negotiation, so that the individual can communicate his or her central objectives, implement changes efficiently and persuade others to achieve the fulfillment of common strategies. In general, this is not an easy task, as it requires sufficient emotional intelligence, empathy and confidence from the individual. These skills can be strengthened through activities designed in learning environments that include the use of digital technologies, such as the use of digital platforms for videoconferencing and case resolution, like MSTeams, and Power point, Canva or Genially for group presentations.

According to Robles (2012), employers consider soft skills to be a significant and important attribute for job applicants, as soft skills of new employees are required to be as highly regarded as hard skills, as requirements have changed (Pitan, 2017). Thus, both employers and higher education institutions have not only realized the need to provide graduates with the competencies and skills that facilitate their incorporation into the labor market, but also allow them to adapt better.

In this context, collaborative work has generated a great deal of attention, as essential skills are discussed in an increasingly globalized, dynamic and complex world. Requiring graduates to be able to solve specific work problems, to have the necessary skills to face new challenges and the ability to negotiate (Baneres & Conesa, 2017).

Few researches focus on the level of students' acquisition of different skills applied to collaborative work, in support of learning throughout their university education, the same happens with researches focused on establishing the relationship of collaborative work skills and the specific socio-academic characteristics of students. In this sense studies such as the one conducted by Al-Alawneh and Ashour (2011), Beigi and Shirmohammadi (2012), Chamorro-Premuzic et al, (2010), Lozano-Rodriguez et al. (2020) and Rodríguez-Gómez et al. (2018), have attempted to establish possible relationships between collaborative work skills and gender, academic experience, or academic performance.

The UANL, in its vision 2030, considers multi-, inter- and transdisciplinary collaborative work within the institutional attributes, establishing it as "the configuration of intellectual and institutional work, in which experts from various disciplines are integrated into teams to face with greater probability of success, and with a high ethical sense, complex issues raised by reality" (UANL, 2022, p. 73)

For this reason, an academic project should be established through a scheduled methodology to develop collaborative work in engineering students through the Integrated Learning Product (ILP), limiting it in a first phase to those taking the Ethics, society and profession learning unit, establishing as justification what the labor field is requesting.

Target

The general objective is to develop the soft competence of collaborative work in students of Ethics, Society and Profession through activities of a pedagogical methodology that allows monitoring and measuring the development of the Integrated Learning Product.

Specific objectives:

Establish an appropriate pedagogical methodology to develop collaborative work in accompanying the design and construction of their IPA, with activities designed in a learning environment that allows monitoring and measurement.

Analyze through surveys and reports the development of the collaborative work competency with the implemented methodology.

Method

The method used for the analysis of this project is quantitative which, according to Hernández Sampieri, et al, (2014), which consists of collecting data, analyzing, establishing guidelines and testing theories, and the non-probabilistic sample criterion will be used, where the selection depends solely on the characteristics for the research, having as the object of study a universe of 530 undergraduate level students studying between seventh and ninth semester of any of the ten educational programs offered by the School of Engineering of a Northeastern Public University and who meet the requirement of being taking the Ethics, Society and Profession Learning Unit.

In the first stage of the project planning, the Goldstein and Col, 1978 social skills questionnaire was selected for the application of this study, which was adapted and translated in (1995) by Tomás, where six dimensions are grouped to analyze from basic social skills to planning skills. This instrument has already been validated, so it has reliability, Bautista, 2011 and it is an ipsative test that, according to Cattell, 1998 is a multiscale measurement, which can be applied individually.

The items related to the questionnaire are composed of 50 items, within the procedure and data collection for subsequent analysis according to the type of questions, the Likert scale was used with five response options to choose from: 1 Is never uses the skill, 2 Rarely uses the skill, 3 Sometimes uses the skill, 4 Often uses the skill and 5 Always uses the skill or almost always. Respondents will answer the instrument through the digital platform. Once the answers are available, they will be analyzed, in order to consecutively define the learning strategies that will be carried out focused on the student, in order to later use the methodology that supports the development of soft skills, specifically collaborative work.

Results

Clear presentation of the results obtained. The overall objective of the project is to identify whether soft skills are developed in the pilot groups, in particular, collaborative work. Among the expected results is to identify whether students develop the ability to work collaboratively, taking into consideration the Integral Learning Product, which in this case is a Research Project applying scientific methodology where they solve a problem or ethical conflict in the field of engineering, so that they can, through active learning strategies, develop effective collaborative work.

The design of the learning environment during the first phase will be applied only to certain pilot groups so that the researchers can have control of the results. We hope that the second phase will include sharing the experience of the researchers with other members of the Academy in order to replicate the project by proposing different strategies or providing feedback on the impact on the different groups. And, finally, in a third phase, a survey was applied to employers, so that they can express whether the engineering graduate has developed the ability to work collaboratively and, if so, apply it to the other learning units of the academic unit or, if not, make the necessary adjustments to the project so that it meets the objective established at the beginning.

Once the instrument was applied, and through the teachers' experience with the pilot groups, it was found that students perform adequately in the collaborative activities, which in this case were implemented through the MSTeams platform. This tool allows work teams to collaborate on Microsoft documents, so that the teacher can track the participation of each team

member, and account for the participation and the degree of contribution. This methodology opens the opportunity for students to negotiate and make decisions while advancing in the development of the research, they can also generate virtual meetings that can be recorded as evidence of the collaborative work.

Analyzing the results of the applied instrument, it stands out that the students consider that they choose the best way to integrate themselves in a work group before a certain activity with 19.6%, while 40.4% say that it happens quite frequently and only 2.5% consider that they do it very seldom. Meanwhile, in the area of negotiation, only 10.2% of the students who responded to the survey favored it, while 45.5% said that it happens to them only sometimes. And when it comes to establishing a negotiation system during the performance of the activity, 21.7% favor it, while 21.2% say only sometimes. On the subject of empathy during communication, 30.6% say they look for it very often, while 21.3% say it only happens sometimes. Finally, on the subject of agreements and decision making, 36.2% seek to resolve difficult situations in collaborative activities, while only 1.9% say that they rarely seek to do so.

Discussion and conclusions

Finally, university graduates must be efficient in their professional performance. For this purpose, not only solid hard competencies are required, but also soft skills that enable them to solve real-life problems. One of the functions expected of higher education institutions is to provide training in soft skills such as: problem solving, critical thinking and collaborative work, among others, so that this research project allows the development of these skills, in particular that of collaborative work.

Training in the engineering area is strongly focused on the development of hard competencies, being problematic to include these skills as pointed out by Hirsch, (2017). Therefore, the importance of this project and the methodology applied, in which the teacher's accompaniment in the development of the PIA throughout the semester through the MSTeams platform and face-to-face sessions, has made it possible to guarantee the integral formation of the student, favoring the development of social skills, not only collaborative work, but also effective communication, negotiation, collaboration and leadership. Some of the observations from the implementation of this methodology, is that by opening up the research project and allowing for an introduction to ambiguity (leaving open-ended instructions for students to make all decisions about the topic, and proposing solutions) creates a space for students to think, research and collaborate so that they can come up with possible solutions and make decisions about which one they think is best, substantiate it and then determine its real-life application. This is an approach to the reality of contexts in the 21st century, where problems are complex (Eiris, Wen & Gheisari, 2022), perhaps not well defined and the answer is not obvious to professionals, who will need to collaborate in multidisciplinary teams looking for possible solutions and applying experience and knowledge (NCR, 2011). the last section will present the conclusions of the article and then the main conclusions. Where appropriate, limitations and proposals for continuity will be included.

References

Al-Alawneh, M.K., & Ashour, R. (2011). Assessing the level of employability skills among graduates of career and technical education institutions in Jordan: An educator perspective. J*ournal of Institutional Research South East Asia*, 9(1), 90-98.

Baneres, D., & Conesa, J. (2017). A life-long learning recommender system to promote employability. *International Journal of Emerging Technologies in Learning (iJET), 12*(06), 77-93. https://doi.org/10.3991/ijet.v12i06.7166.

Bautista, C. N. P. (2011). *Proceso de la investigación cualitativa: epistología, metodología y aplicaciones.* Manual Moderno.

Beigi, M., & Shirmohammadi, M. (2012). Attitudes toward teamwork are Iranian university students ready for the workplace. *Teams Performance Management*, *18*(5/6), 295-311. https://doi.org/10.1108/13527591211251087.

Catell, R. B. (1988) The data box: Its ordering of total resources in terms of possible relational systems. In J.R. Nesselroade y R. B. Catell (Eds.) *Handbook of multivariate experimental psychology*. Plenum Press.

Chamorro-Premuzic, T., Arteche, A., Bremner, A. J., Greven, C., & Furnham, A. (2010). Soft skills in higher education: Importance and improvement ratings as a function of individual differences and academic performance. *Educational Psychology*, *30*(2), 221-241. https://doi.org/10.1080/01443410903560278.

Eiris, R., Wen, J., & Gheisari, M. (2022). iVisit-Collaborate: Collaborative problem-solving in multiuser 360-degree panoramic site visits. *Computers & Education*, *177*, 104365.

García, E. (2016). The need to address non-cognitive skills in the education policy agenda. In M.S. Khine and S. Areepattamannil (eds.), *Non-cognitive skills and factors in educational attainment* (pp. 31-64). Sense Publishers. https://doi. org/10.1163/9789463005913_004

García, B. (2018) Las habilidades socioemocionales, no cognitivas o "blandas": aproximaciones a su evaluación. *Revista Digital Universitaria (RDU). 19*(6). http//doi-org/10.22201/codeic.16076079e.2018.v19n6.a5

Goldstein, A., Col, (1978). Escala de Habilidades sociales.

Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, P. (2014). *Metodología de la Investigación* (6ª Ed.). Mc Graw Hill.

Hirsch, B. J. (2017). Wanted: soft skills for today's jobs. *Phi Delta Kappan*, *98*(5), 12-17. https://doi.org/10.1177/0031721717690359.

Lippman, L.H, Ryberg, R., Terzian, M., Moore, K.A., Humble, J., & McIntosh, H. (2014). Positive and protective factors in adolescent well-being. In A. Ben-Arieh, F. Casas, I. Frones and J.E. Korbin (eds), *Handbook of child well-being: Theories, methods and policies in global perspective* (pp. 2823-2966). https://doi.org/10.1007/978-90-481-9063-8_141.

Lozano-Rodríguez, A., García-Vázquez, F. I., Zubieta-Ramírez, C., & López-Cruz, C. S. (2020). Competencies associated with Semestre I and its relationship to academic performance: A case study. *Higher Education, Skills and Work-Based Learning, 1*0(2), 387-399. https://doi.org/10.1108/HESWBL-07-2019-0092.

National Research Council. (2011). Assessing 21st century skills: Summary of a workshop. In J.A. Koening & Rapporteur. In *Committee on the Assessment of 21st Century Skills* (Eds.) Washington, DC The National Academies Press.

OCDE. (2016) PISA 2015 PISA, Resultados Clave. https://www.oecd.org/pisa/pisa-2015-results-in-focus-ESP.pdf

OECD (2019). Educación superior en México: Resultados y relevancia para el mercado laboral, OECD Publishing, Paris, cap. 5 Aumentar la relevancia y los resultados de la educación superior en el mercado laboral. https://doi.org/10.1787/a93ed2b7-es.

Ortega, E. (2016). Una estrategia para la formación de competencias blandas desde edades tempranas. *Revista Cubana de Educación Superior, 2*, 35-41

Pandey, V.K., Shukla, S., & Singh, B. (2022). Impact and influence of soft skill training on the employability of engineering and management graduate and post graduate students: A review. https://doi.org/10.30574/wjaets.2022.5.1.0005

Pitan, O.S. (2017). Graduate employees' generic skills and training needs. Higher Education, *Skills and Work-Based Learning*, *7*(3), 290-303. https://doi.org/10.1108/HESWBL-04-2017-0026.

Robles, M.M. (2012). Executive perceptions of the top 10 soft skills needed in today's workplace. *Business Communication Quarterly, 75*(4), 453-465. https://doi.org/10.1177/1080569912460400

Rodríguez-Gómez, G., Ibarra-Saiz, M.S., & Cubero-Ibañez, J. (2018). Competencias relacionadas con la evaluación. Un estudio sobre la percepción de los estudiantes. Educación XXI, *21*(1). https://doi.org/10.5944/educXX1.14457.

Tomás, A. (1995). *Manual de calificación y diagnóstico de la Lista de Chequeo de Habilidades Sociales de Goldstein.*

UANL (2022). *Plan de Desarrollo Institucional 2022-2030 de la Universidad Autónoma de Nuevo León.* UANL.

Yan, L., Yinghong, Y., Lui, S.M., Whiteside, M., & Tsey, K. (2019). Teaching "soft skills" to university students in China: The feasibility of an Australian approach. *Educational Students, 45*(2), 242-258. https://doi.org/10.1080/03055698.2018.1446328.