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PRESENTATION

The Language Program of the Post-Grade School of the "National University of the Altiplano" contributes to the teaching and updating of the English language, in order to promote the publication of scientific research works carried out by graduate students. on different areas of knowledge applied to the reality of the region. Social, environmental and economic conflicts begin to appear with emphasis in this century. Therefore, research is needed to help solve these problems. The participants in the course have committed themselves to actions that lead to contribute knowledge to science and bet on an integrated approach to address social, economic and environmental areas. The papers researched in this book develop general topics that need knowledge, including topics on environment, medicine, social responsibility, culture and agriculture, which offers a holistic theoretical framework and its application to recommend changes in institutional policies, social and environmental benefits for our country. Finally, the text is the result of a continuous research process undertaken by an interdisciplinary team of professionals from different areas of the Puno region, who contribute their scientific work in various areas of human knowledge.

Dr. Mario Silva Dueñas

English Teacher

Social Sciences



EFFECTIVENESS OF INCREASED PENALTIES AS A GENERAL PREVENTION MECHANISM AND ITS IMPACT ON THE REDUCTION OF CRIMINALITY IN PERU

Antonio Flores, Midwiss Vladimir

ABSTRACT

Miguel de Cervantes Saavedra alluded: 'Crimes carry the punishment on their backs', in the sense that the perpetrator of a crime is inexorably entitled to a penal consequence as a sanction. Thus, the special importance of the function and purposes of punishment is assumed, seeking to balance the penalty for the crime committed with the protection of citizens and the social reintegration of the sentenced individual. The functions of punishment are held as: *general prevention* (deterrence), *special prevention* (rehabilitation), and *just retribution* (proportionality to the illicit act), leading to a criminal law called upon to fulfill a function of general prevention. In Peru, a trend has emerged in recent years where the legislator increases criminal penalties for certain offenses as a general prevention mechanism to reduce their incidence. This represents an illusory claim by the legislator, as this 'form' of prevention does not affect the reduction of crime rates. In the present study, we seek to confirm this thesis by drawing on supporting doctrinal foundations, as well as statistics related to the commission of crimes following the legislated increase in penalties. For the case under study, (we will consider the crime of Aggression against women or family group members, provided for and sanctioned under Article 122-B of the Peruvian Penal Code), in order to determine whether increasing penalties is effective as a general prevention mechanism and if such an increase has a direct relationship with a decrease in its incidence.

Keywords: Crime, Punishment, Purposes of Punishment, Increase in Punishment, General Crime Prevention, Crime Incidence.

INTRODUCTION

In Peru, regarding the *Purposes of Punishment and Security Measures*, Article IX of the Preliminary Title of the Penal Code states *that punishment* has preventive, protective, and re-socializing functions, while *security measures* pursue goals of

healing, guardianship, and rehabilitation. Thus, the substantive regulations suggest a primary *preventive* purpose aimed at deterring the commission of crimes; a secondary *protective* purpose seeking to safeguard society and the legal interests protected by criminal law; and, fundamentally, a re-socializing purpose, as it seeks the re-education and rehabilitation of the sentenced individual. This follows an *eclectic theory*, whose foundation lies in: 'crime prevention (special prevention and general prevention) and the retribution of harm, with a strong preponderance of special prevention.' (Farfán, 2021), in summary, the Preventive Function (General) aims to deter the commission of crimes through the imposition of a penalty, while the re-socializing Function (Special Prevention) intends for the execution of the sentence to be oriented toward the re-education, rehabilitation, and subsequent reintegration of the individual into society, as legislated in the Code of Criminal Execution. It is emphasized that the penalty cannot exceed the responsibility for the act, and that security measures must pursue the healing, guardianship, and rehabilitation of the sentenced individual.

At the jurisprudential level, the Supreme Court of Justice of the Peruvian Republic has ratified that the aforementioned preventive theories—both special and general—enjoy direct constitutional protection, stating that:

Preventive theories, both special and general, enjoy direct constitutional protection insofar as, as will be seen, their objectives are consistent with the principle-right of dignity and the double dimension of fundamental rights; being, therefore, the best means of crime repression, which has been recognized by the Constituent Power as an evil generated against interests that are particularly transcendent to guarantee the minimum conditions for a harmonious coexistence in a democratic society (Corte Suprema de Justicia de la República del Perú, 2015). Underlining added.

In this line of reasoning, the Supreme Court, through a Resource of Annulment, reiterated that the preventive purpose of punishment presents two orientations for its fulfillment: the general (mediate) and the special (immediate), sustaining that they are:

The first, which intimidates the collective with the purpose of preventing the commission of crimes and is embodied in the legal threat [abstract penalty for each crime]; [...] the second directly influences the agent, seeking their re-education, rehabilitation, and reintegration into society, whose action occurs at the time of the judicial determination of the penalty; therefore, when establishing the penalty, its special preventive purpose prevails, (Corte Suprema de Justicia de la República del Perú, 2015). Underlining added.

Furthermore, regarding the principle that the penalty must allow the sentenced individual an opportunity to amend their actions, it [the Court] has stated that:

In the present case, there are well-founded grounds to impose a severe sanction; however, it must be considered that the defendants have no prior judicial records, [...] that at the time of the commission of the acts, [...] one was twenty-two years old and [...] the other was twenty-six, and that their level of education is completed secondary school and incomplete secondary school, respectively. These circumstances empower the judge to reduce the specific penalty, for which it must be considered that its purpose is to achieve recovery and, consequently, the reintegration of the sentenced individual into society. Therefore, such a sanction must allow the defendant to have an opportunity to amend their actions; even more so if modern criminal law assumes the basic doctrinal principles of minimal intervention, humanity, protection, prevention, and resocialization of punishment, contained in the Political Constitution of Peru —every penalty must promote the resocialization of the inmate, both in the legislative facet and in the judicial field and the scope of criminal execution— and in the Preliminary Title of the Penal Code (Corte Suprema de Justicia de la República del Perú, 2019), underlining added.

Finally, the supreme interpreter of the Peruvian Political Constitution points out that: 'A State founded on the right-principle of human dignity and the democratic political principle cannot distinguish between a criminal law for citizens and a criminal law for the enemy' (Tribunal Constitucional del Perú, 2006), underlining added.

The Peruvian legal system, by increasing penalties in substantive law, has shifted from a 're-socializing' model to one of 'special prevention' and 'severe punishment,' under the idea that the defendant should 'know' that committing such a crime will likely result in an effective custodial sentence. Thus, the possibilities for suspended sentences provided in Article 57 of the Penal Code have been normatively restricted, granting judges the power to issue effective sentences based on aggravating circumstances. Likewise, the conversion of a sentence to community service is limited, requiring the judge to verify, among other things, the lack of a criminal record and a low risk level for the victim. Furthermore, the failure to comply with protection measures issued by the jurisdictional body in favor of the aggrieved party is erroneously classified as Resistance or Disobedience to Authority under Article 368 of the Penal Code (*an offense penalized with no less than five nor more than eight years*), when such illicit conduct should be classified as an aggravating circumstance of the crime of 'Aggressions against women or family group members.' Indeed, subsection 6 of Article 122-B is clear in its legislation,

establishing criminal liability for *'whoever contravenes a protection measure issued by a competent authority' (an offense penalized with no less than two nor more than three years)*. Thus, legislation is observed to be issued without justifying whether a correspondence exists between the increase in the penalty and its incidence, omitting the nature *of the function and purposes of punishment* and the *intervention of criminal law*—given that punishment constitutes a substantial axis of criminal law, considering that, following Roxin:

Our Penal Code provides, alongside penalties, security measures as well; and this double-track system of sanctions marks the fundamental structural element of our regulation of legal consequences. Following the discussion of penal theories, it is likewise understood why a criminal law committed to the principle of guilt requires the second track of security measures: the self-restriction of the State's coercive intervention, which is based on the measure of guilt, certainly enables—as a general rule—an adequate balance between the State's protection interests and the defendant's interests in liberty; (Roxin, 1997). Underlining added.

METHODS

To approach this phenomenon with academic rigor, a *mixed-methods research* approach will be adopted, as it integrates qualitative and quantitative tools, which is consistent with the legal-social nature of the object of study. The analysis of increased penalties cannot be limited to a normative reading; instead, it requires contrasting criminal policy with empirical data on criminality.

The descriptive level allows for the identification of the normative and criminological evolution associated with punitive hardening, while the analytical-critical level enables an examination of legislative rationality, the purposes of punishment, and the coherence of punitive increases with contemporary criminal law principles.

The non-experimental design responds to the impossibility of manipulating variables, limiting the study to the observation and analysis of phenomena that have already occurred. Likewise, a cross-sectional design is employed for the normative analysis, alongside a longitudinal descriptive design to study the evolution of criminality within the delimited period.

The legal methods utilized include the dogmatic method, oriented toward the systematic interpretation of the criminal justice system; the analytical method, aimed at deconstructing the elements of criminal policy; and the comparative method, applied to the contrast between criminal reforms and their criminological

impact. Complementarily, the descriptive statistical method is used to analyze official data provided by the Indicators Department of the Public Prosecutor's Office of the Public Ministry in the Fiscal District of Puno. According to the Fiscal Management System, it is verified that between the years 2023 and 2024, the number of complaints for the crime of Aggression against women and family group members has increased (independent variable: punitive hardening vs. dependent variable: number of complaints).

RESULTS AND DISCUSSION

It is verified that our criminal legislation, regarding the case under study—the crime of 'Aggression against women or family group members'—has undergone numerous amendments. We cite the most relevant ones, which demonstrate an increase in custodial sentences and even the creation of new criminal figures—*offenses*—criminalizing them with severe penalties:

Article 30-A.- Application of restrictive liberty penalty as an accessory penalty

Expulsion, regulated in Article 30, is applied as an accessory penalty in the crimes typified in the following articles: [...] 122-B, [...] (*)

(*) Article incorporated by Article 3 of Legislative Decree No. 1573, published on October 5, 2023 (Sistema Peruano de Información Jurídica (SPIJ), 2026).

This article establishes expulsion as an accessory penalty for the commission of the crime of 'Aggression against women or family group members.'

Last paragraph modified by the Single Article of Law No. 30710, published on December 29, 2017, which reads as follows:

The suspension of the execution of the sentence is inapplicable to [...], as well as for persons convicted of the crime of aggression against women or family group members under Article 122-B, [...]. (Sistema Peruano de Información Jurídica (SPIJ), 2026)

This article establishes that the suspension of the sentence is inapplicable to defendants convicted of the crime of 'Aggression against women or family group members.

Article 122-B.- Aggression against women or family group members
Whoever, by any means, causes bodily injuries requiring less than ten days of medical assistance or rest according to medical prescription, or any type of psychological, cognitive, or behavioral affection that does not qualify as

psychic damage to a woman due to her status as such, or to family group members in any of the contexts provided for in the first paragraph of Article 108-B, shall be punished with a custodial sentence of no less than one nor more than three years and disqualification in accordance with numerals 5 and 11 of Article 36 of the present Code and Articles 75 and 77 of the Children and Adolescents Code, as applicable.

The penalty shall be no less than two nor more than three years when the following aggravating circumstances occur within the scenarios of the first paragraph:

1. Any type of weapon, blunt object, or instrument that endangers the victim's life is used.
2. The act is committed with cruelty or treachery.
3. The victim is pregnant.
4. The victim is a minor, an elderly person, has a disability, or suffers from a terminal illness, and the agent takes advantage of such condition.
5. Two or more people participate in the aggression.
6. A protection measure issued by the competent authority is contravened.
7. The acts are performed in the presence of any girl, boy, or adolescent. (*)

(*) In accordance with Article 3 of Law No. 30819, published on July 13, 2018, for the crime provided in this article, the criminal judge applies the suspension and extinction of parental rights according to Articles 75 and 77 of the Children and Adolescents Code, as appropriate to the procedural moment. It is prohibited, under liability, to order that such matter be resolved by specialized family justice or its equivalent. (Sistema Peruano de Información Jurídica (SPIJ), 2026).

In the aforementioned Article, we highlight the following: Article 122-B was initially created as an aggravated form of the crime of Minor Injury due to family violence, specifically when the damage to the body or health required more than ten and less than thirty days of medical assistance or rest, according to medical prescription. Such illicit conduct was punished with a custodial sentence of no less than three nor more than six years and the suspension of parental rights (*Article incorporated by Article 12 of Law No. 29282, published on November 27, 2008, in the Official Gazette 'El Peruano', subsequently repealed by the First Complementary Repealing Provision of Law No. 30364, published on November 23, 2015*), it was later modified by *Article 2 of Legislative Decree No. 1323,*

published on January 6, 2017, and by *Article 1 of Law No. 30819*, published on July 13, 2018. These reforms established, in addition to the first four aggravating circumstances, the aggravations contained in subsections 5 to 7, as currently legislated. Furthermore, disqualification was added to the aggravating circumstances, which was initially established as the suspension of parental rights. Finally, it is established that such aggressions must occur within the contexts specified in Article 108-B of the Penal Code (referral norm); that is, they must take place within the context of: Family violence; Coercion, harassment, or sexual stalking; Abuse of power, trust, or any other position or relationship granting authority to the agent; and any form of discrimination against women, regardless of whether a conjugal or cohabitation relationship exists or has existed with the agent. Only in such situations will said crime be constituted.

Furthermore, what was noted above regarding the increase in penalties has influenced other aspects, such as Penitentiary Benefits, involving their proscription and new parameters for their granting, without considering their commission and incidence in relation to the purposes of penitentiary treatment, which seeks to rehabilitate, re-educate, and reintegrate the sentenced individual into society.

Regarding the crime incidence of 'Aggression against women or family group members,' information gathered from the Indicators Department of the Public Prosecutor's Office of Public Ministry in the Fiscal District of Puno verifies that, according to the number of complaints recorded in the Fiscal Management System for the year 2023, these have increased in the year 2024 despite the aforementioned punitive hardening used as a prevention mechanism, as follows:

Table 1

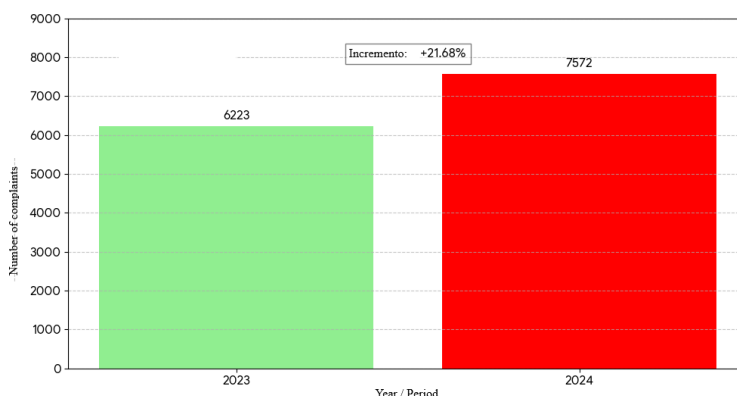
Cases registered in the fiscal district of Puno

Crime	Fiscal district	Period	
		2023	2024
Aggression against women or family group members	Puno	6223	7572
Total of cases		6223	7572

Source: Information gathered from the Fiscal Management System of the Fiscal District of Puno.

Figure 1

Increase in cases of aggression against women or family group members: evidence of the inefficiency of punitive hardening as a deterrent factor in its incidence.



Source: Prepared by the author.

Therefore, it is as follows *Evidence of Inefficiency* in the data shows that despite legal reforms and the hardening of penalties, the curve remains upward. Regarding the *Empirical Contrast*, if increasing penalties were an effective general prevention mechanism, the 2024 figure should be lower than or equal to that of 2023. However, the statistical reality—an increase of 1,349 cases—demonstrates that the severity of the penalty does not act as a real deterrent in the incidence of 'Aggression against women or family group members' in the Fiscal District of Puno. This leads to a *Visual Conclusion*: the gap between both columns represents the "failure" of criminal policy based exclusively on retribution (increased penalties).

The data reveals a critical increase of 21.68% in family violence complaints in just one year. This empirical evidence supports the research title: "*Effectiveness of Increased Penalties as a General Prevention Mechanism and its Incidence in the Reduction of Crime in Peru*," specifically regarding Article 122-B of the Penal Code.

The General Prevention Theory suggests that increased penalties should deter citizens from committing crimes through fear of punishment. However, the data proves the opposite: while penalties have been hardened within the Peruvian normative framework, the number of cases escalated from 6,223 to 7,572, establishing the failure of Negative General Prevention.

This increase of 1,349 additional cases suggests that potential offenders do not make decisions based on the calculation of penalty severity, confirming the Invariability of the Crime Rate in the face of punitive hardening.

These findings suggest that "iron fist" policies or punitive populism are insufficient. The sustained increase in complaints indicates that the problem is structural and that the effectiveness of criminal law as the sole social control mechanism is limited. Therefore, legislation must be established within the parameters of a Comprehensive Criminal Policy.

In summary, the legislator imposes increasingly severe sanctions with the aim of curbing their commission; however, there are crimes of ideological or pathological origin for which the gravity of the penalty is neither a deterrent nor a preventive component. On the contrary, high crime rates must be countered with Criminal Policies aligned with the social reality of each sector of the country, as ours is a pluricultural nation. Furthermore, we overlook pertinent sciences conducive to combating this phenomenon, such as Criminology, which allows for the study of the offender, the crime scene, the crime itself, deviant behavior, and social control—without neglecting the victim—to understand the perpetrator and the motivations behind their illicit conduct. This is especially relevant since Criminology centers its study on the prevention and treatment of such deviant behaviors, ensuring that the legal system does not resort to mere over-penalization to 'combat' crime incidence. Methods other than over-penalization exist to address criminal rates, particularly since our already overcrowded prison system fails to fulfill its purpose of re-socializing, re-educating, and reintegrating the convicted into society, only succeeding in further overpopulating penitentiary centers through the measures enacted.

Furthermore, it is observed that the legislator, through the aforementioned actions, affects the reasonableness of punishment based on the nature of the crime and the culpability of the agent, forgetting that the penalty must be consistent and reasonable regarding the gravity of the committed offense and not excessive. There should be no lapse into disproportion or insignificance that implies triviality, as the imposition of a penalty is necessary to protect society; however, its excess must be proscribed, avoiding communicative effects that encourage lynchings or disproportionate measures such as 'vigilante justice.' It is crucial to avoid a doctrine that distinguishes between *'citizens' who respect the law and 'enemies' who systematically violate it'*—anticipating punishability, reducing procedural guarantees, and increasing penalties to neutralize risks in order to prioritize security over individual guarantees. Following Günther Jakobs: 'not every offender is an adversary [...] the introduction of—a now practically unmanageable—cluster of lines and fragments of Enemy Criminal Law into General Criminal Law is an evil

from the perspective of the Rule of Law.' (Jakobs & Cancio, 2003) (Page 48), establishing that Criminal Policies must be adopted to mitigate crime rates and guarantee the protection of the State's essential interests and citizens' rights. These policies can be social, promoting neighborhood intervention through security committees to prevent crime by alerting the Peruvian National Police and acting through 'citizen's arrest'; legal, by reforming criminal norms to reinforce the preventive, protective, and re-socializing functions of punishment, ensuring security measures fulfill their purposes; or cultural, utilizing mass media (including the internet and social networks) to raise awareness about the consequences of social conduct that affects protected legal interests, potentially involving Crime Prevention Prosecutor's Offices for this purpose and furthermore, it is necessary to resort to Criminology as an empirical and interdisciplinary science focused on the study of the offender, the crime scene, the crime itself, deviant behavior, and social control. Its objective is to understand the criminal and the various motivations that led to the offense, focusing on prevention and the treatment of deviant behaviors. The terms 'Policy' and 'Criminology' combined refer to the study of criminogenic causes and factors. Ultimately, there is no direct relationship between increased penalties and a reduction in crime incidence; the legislator errs in the fight against criminality by over-penalizing its commission, thereby failing to fulfill the purpose and functions of punishment.

CONCLUSIONS

The Peruvian penal system has experienced a progressive trend toward increasing custodial sentences, materialized through successive legislative reforms to the Penal Code and special laws. This normative evolution evidences a criminal-policy orientation based on punitive hardening—increased penalties—as a general prevention mechanism against the perceived increase in crime. However, the severity of the sanction as a social control strategy to decrease crime incidence does not constitute a determining factor for crime reduction, as criminological evidence shows that the certainty of the sanction and the effectiveness of the criminal justice system have a greater preventive impact than the abstract increase of already established penalties.

Legislative reforms oriented toward increasing penalties within the Peruvian legal system frequently respond to contexts of social and media pressure, shaping phenomena of criminal law expansion or punitive populism, where criminal legislation is used as a symbolic instrument of state response to increasing citizen insecurity.

It has been identified that the increase in penalties generates relevant collateral effects in the criminal system, particularly in the growth of the prison population,

the institutional overcrowding of the penitentiary system, and the State's limited capacity to guarantee effective resocialization processes. This compromises the constitutional purposes of punishment, failing to fulfill the objective of the penitentiary system regarding the resocialization, re-education, and reintegration of the sentenced individual into society.

From a constitutional and guarantee-oriented perspective, the indiscriminate increase in penalties creates a tension with fundamental principles of criminal law, such as proportionality, minimal intervention, and the rationality of criminal policy, which constitute limits to the exercise of *ius puniendi* in a constitutional state of law.

The increase in penalties, by itself, does not constitute an effective criminal policy to reduce crime incidence. It is necessary for crime prevention strategies to be oriented toward comprehensive policies that include institutional strengthening, social crime prevention, investigative efficiency, and social reintegration policies. Therefore, a rational criminal policy must be based on empirical, criminological, and constitutional criteria, avoiding the use of increased penalties as an automatic response to criminal phenomena, and promoting legislative reforms consistent with the principles of modern criminal law and the effective protection of protected legal interests.

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SELF-ESTEEM AND ALCOHOL USE AMONG ADOLESCENTS IN A PUBLIC ANDEAN SCHOOL IN SOUTHERN PERÚ

Apaza Loayza, Alexis Nímer

ABSTRACT

This study examined the association between self-esteem and alcohol use among adolescents attending a public school in Puno, Perú. A quantitative, cross-sectional correlational design was used with 104 fifth-year secondary school students. Self-esteem was assessed with the Coopersmith Self-Esteem Inventory, and alcohol use was measured with the Alcohol Use Disorders Identification Test (AUDIT); both instruments showed adequate reliability. The findings indicated that global self-esteem was not significantly associated with alcohol use. However, the personal self-esteem and school-academic self-esteem dimensions showed small but significant inverse correlations with alcohol use. These results suggest that, although global self-esteem may not explain adolescent alcohol use in this sample, specific self-esteem domains appear relevant for understanding this behavior and for informing school-based preventive interventions.

Keywords: self-esteem; alcohol use; adolescence; school health; emotional well-being.

INTRODUCTION

Alcohol use during adolescence remains a major public health concern because of its effects on students' psychological, emotional, and social development. Previous studies have shown that early alcohol initiation and heavy drinking patterns are associated with greater emotional vulnerability and poorer self-regulation, thereby increasing the risk of short- and long-term behavioral problems (Castelli et al., 2022).

Recent evidence suggests that adolescent alcohol use cannot be explained solely by peer influence. Rather, it is closely linked to psychological and emotional factors. Longitudinal studies have shown that internalizing symptoms, such as anxiety and depression, increase the likelihood of alcohol use, suggesting that

drinking may function as a coping response to emotional distress when personal coping resources are limited (Gohari et al., 2023).

Within this framework, self-esteem is particularly relevant because it shapes perceived competence, decision-making, and the ability to cope with social pressure. Recent research has shown that lower self-esteem is associated with greater vulnerability to risk behaviors, partly because it weakens adaptive coping processes and favors maladaptive responses to stress (Pereira et al., 2025).

Conceptually, self-esteem can be understood as a global evaluation of self-worth and as an important foundation of adolescent psychological well-being (Rosenberg, 1965). Longitudinal evidence has documented developmental changes in self-esteem and their association with psychosocial outcomes (Orth & Robins, 2014). Meta-analytic findings have also shown that low self-esteem is associated with an increased risk of internalizing symptoms such as depression and anxiety, which may in turn heighten vulnerability to maladaptive coping behaviors (Sowislo & Orth, 2013). At the same time, high self-esteem does not automatically guarantee positive outcomes in every domain, and its role should therefore be interpreted within a broader contextual framework (Baumeister et al., 2003).

Stress and difficulties in emotion regulation have likewise been identified as important predictors of alcohol use among adolescents. Empirical evidence suggests that young people with fewer emotional resources for managing stress are more likely to increase their alcohol use, particularly in settings marked by high emotional and social demands (Sharma et al., 2022). These findings highlight the importance of examining alcohol use from a comprehensive perspective that includes both contextual and individual factors.

In Latin America, adolescent alcohol use is shaped by sociocultural and contextual conditions that may increase vulnerability, especially in settings characterized by socioeconomic constraints and limited access to mental health services. Research in the region has shown that, under conditions of social vulnerability, alcohol use may intensify when emotional support and personal resources are weakened (Monzon et al., 2024). In addition, recent population-level data indicate that alcohol use remains common among secondary school students despite school-based prevention efforts (Hoots et al., 2023). In Peru, the *National Study on Drug Use Among Secondary School Students 2024* reported a 12-month alcohol use prevalence of 24.1%, with higher rates among girls (27.7%) than among boys (20.6%) (Comisión Nacional para el Desarrollo y Vida sin Drogas, 2025).

Against this background, this study examined the association between self-esteem and alcohol use among fifth-year secondary school students in southern Peru, considering both global self-esteem and its specific dimensions. The study

seeks to contribute empirical evidence to clarify the role of psychological factors in adolescent alcohol use and to support the design of preventive strategies in educational settings.

METHOD

This study used a quantitative approach with a cross-sectional, non-experimental correlational design. This design made it possible to examine the association between self-esteem and alcohol use at a single point in time without manipulating the study variables.

The study included 104 fifth-year secondary school students from a public school in southern Peru. Because all eligible students were included, a census sampling approach was used. Participants had broadly similar sociodemographic characteristics and took part voluntarily.

Self-esteem was assessed using the Stanley Coopersmith Self-Esteem Inventory, an instrument used in adolescent populations to evaluate both global self-esteem and its specific dimensions: personal, social, school-academic, and family self-esteem (Coopersmith, 1981). Previous psychometric studies have reported evidence of reliability and validity for this instrument (Chiu, 1985). Alcohol use was assessed with the Alcohol Use Disorders Identification Test (AUDIT), developed by the World Health Organization (Babor et al., 2001) within the framework of an international collaborative project (Saunders et al., 1993), which makes it possible to identify different levels of alcohol use.

Data collection was carried out in coordination with school authorities, in accordance with ethical principles for research involving human participants. Before the instruments were administered, students were informed about the aims of the study, and confidentiality was guaranteed. The instruments were administered collectively during school hours under the supervision of the researcher, ensuring adequate conditions for comprehension and completion.

Data were analyzed using descriptive and inferential statistics. Spearman's rho was used to assess the association between the variables, with a significance level of .05. Data processing was carried out using statistical software.

Table 1**Operationalization of Variables**

Variable	Dimensions	Instrument/Indicator	Levels (ranges)	Scale
Self-esteem	Total (self, social, home, school)	Coopersmith (dimension scores and total score)	Very low / Low / Normal / High / Very high	Ordinal
Alcohol use	Level of use	AUDIT (10 items)	Low (0–7) / Medium (8–15) / High (16–19) / Probable addiction (20–40)	Ordinal

Finally, the operationalization of variables made it possible to organize the analysis in accordance with the study objectives. Self-esteem was addressed at both the global level and across each of its dimensions, using score ranges that allowed it to be classified as very low, low, normal, high, or very high. Alcohol use, in turn, was operationalized according to the levels established by the AUDIT, making it possible to identify the degree of risk associated with drinking. This operationalization is summarized in Table 1 and served as a basis for interpreting the results.

Study Hypotheses

Understanding the predominant psychological characteristics of the study participants is essential for examining the processes that influence their behavior and for supporting timely educational decision-making. Accordingly, this study tested one general hypothesis and a set of specific hypotheses related to the dimensions of the variable under analysis.

The general hypothesis stated that there is a significant association between self-esteem and alcohol use among fifth-year students from the school under study. In contrast, the null hypothesis stated that no statistically significant association exists between the two variables.

Regarding the specific hypotheses, it was proposed that personal self-esteem is significantly associated with alcohol use among the students assessed. The corresponding null hypothesis stated that no significant association exists between these variables.

Likewise, it was proposed that social self-esteem is significantly associated with alcohol use, whereas the null hypothesis stated that no such relationship exists. Similarly, the hypothesis was formulated that family self-esteem is associated with

alcohol use, in contrast to the null hypothesis indicating the absence of such an association.

Finally, it was proposed that school-academic self-esteem is significantly associated with alcohol use among fifth-year students, whereas the null hypothesis stated that no relationship exists between the two variables.

RESULTS

Table 2

Global Self-Esteem and Alcohol Use Level Among Fifth-Year Students

Global self-esteem	Low n	Low %	Medium n	Medium %	High n	High %	Total n	Total %
Very low	24	23.1	2	1.9	3	2.9	29	27.9
Low	8	7.7	0	0.0	0	0.0	8	7.7
Normal	35	33.7	1	1.0	0	0.0	36	34.6
High	15	14.4	0	0.0	0	0.0	15	14.4
Very high	15	14.4	1	1.0	0	0.0	16	15.4
Total	97	93.3	4	3.8	3	2.9	104	100.0

Table 2 shows the association between levels of global self-esteem and alcohol use among the students assessed. Most participants were classified in the low alcohol-use category (93.3%), regardless of self-esteem level. However, students with very low self-esteem accounted for the highest proportions not only in the low-use category (23.1%) but also in the medium (1.9%) and high (2.9%) categories. By contrast, students with high and very high self-esteem were concentrated almost exclusively in the low-use category, with only minimal representation in the medium category and none in the high category. These results suggest that, although alcohol use was predominantly low in the sample, lower self-esteem levels tended to be associated with higher levels of alcohol use.

Table 3

Association Between Personal Self-Esteem and Alcohol Use Among Fifth-Year Students

Personal self-esteem	Low n (%)	Medium n (%)	High n (%)	Total n (%)
Very low	23 (22.1)	2 (1.9)	3 (2.9)	28 (26.9)
Low	14 (13.5)	1 (1.0)	0 (0.0)	15 (14.4)
Normal	33 (31.7)	0 (0.0)	0 (0.0)	33 (31.7)
High	17 (16.3)	0 (0.0)	0 (0.0)	17 (16.3)
Very high	10 (9.6)	1 (1.0)	0 (0.0)	11 (10.6)
Total	97 (93.3)	4 (3.8)	3 (2.9)	104 (100.0)

Table 3 shows the association between personal self-esteem and alcohol use among the students assessed. Most adolescents, regardless of their level of personal self-esteem, were concentrated in the low alcohol-use category. However, students with very low personal self-esteem showed a higher proportion of cases in the medium and high categories compared with those reporting normal, high, or very high personal self-esteem, among whom no cases of high alcohol use were observed. These results suggest that lower personal self-esteem may be associated with greater vulnerability to alcohol use, although this association appears to be of small magnitude.

Table 4

Association Between Social Self-Esteem and Alcohol Use Among Fifth-Year Students

Social self-esteem	Low n	Low %	Medium n	Medium %	High n	High %	Total n	Total %
Very low	34	32.7	2	1.9	2	1.9	38	36.5
Low	20	19.2	0	0.0	0	0.0	20	19.2
Normal	31	29.8	2	1.9	1	1.0	34	32.7
High	6	5.8	0	0.0	0	0.0	6	5.8
Very high	6	5.8	0	0.0	0	0.0	6	5.8
Total	97	93.3	4	3.8	3	2.9	104	100.0

Table 4 shows the association between social self-esteem and alcohol use among the students assessed. Most adolescents, regardless of their level of social self-esteem, were concentrated in the low alcohol-use category. Likewise, cases of

medium and high use were distributed mainly across the very low and normal levels of social self-esteem. However, this association was not statistically significant, suggesting that social self-esteem does not directly influence alcohol-use behavior in the population studied.

Table 5

Association Between Family Self-Esteem and Alcohol Use Among Fifth-Year Students

Family self-esteem	Low n (%)	Medium n (%)	High n (%)	Total n (%)
Very low	18 (17.3)	2 (1.9)	2 (1.9)	22 (21.2)
Low	12 (11.5)	0 (0.0)	0 (0.0)	12 (11.5)
Normal	33 (31.7)	1 (1.0)	1 (1.0)	35 (33.7)
High	28 (26.9)	1 (1.0)	0 (0.0)	29 (27.9)
Very high	6 (5.8)	0 (0.0)	0 (0.0)	6 (5.8)
Total	97 (93.3)	4 (3.8)	3 (2.9)	104 (100.0)

The results presented in Table 5 show the association between family self-esteem and alcohol use among the students assessed. Most participants with normal and high levels of family self-esteem were concentrated in the low-risk alcohol-use category, accounting for 31.7% and 26.9%, respectively. In contrast, students with very low family self-esteem showed a greater presence in the medium and high categories, although in small proportions. These findings suggest that a positive appraisal of family relationships may act as a protective factor against alcohol use, whereas a low perception of family support and understanding may be associated with greater risk.

Table 6

Association Between School-Academic Self-Esteem and Alcohol Use Among Fifth-Year Students (n = 104)

School-academic self-esteem	Low n (%)	Medium n (%)	High n (%)	Total n (%)
Very low	4 (3.8)	1 (1.0)	2 (1.9)	7 (6.7)
Low	10 (9.6)	0 (0.0)	1 (1.0)	11 (10.6)
Normal	48 (46.2)	3 (2.9)	0 (0.0)	51 (49.0)
High	17 (16.3)	0 (0.0)	0 (0.0)	17 (16.3)
Very high	18 (17.3)	0 (0.0)	0 (0.0)	18 (17.3)
Total	97 (93.3)	4 (3.8)	3 (2.9)	104 (100.0)

Table 6 presents the association between school-academic self-esteem and alcohol use. The largest proportion of students fell within the normal school-academic self-esteem category and was concentrated mainly in the low alcohol-use category (46.2%). High and very high levels of school-academic self-esteem were associated exclusively with low alcohol use, whereas medium and high alcohol use were concentrated in the very low and low school-academic self-esteem categories.

Spearman's rho was used to examine the association between self-esteem and alcohol use among fifth-year students. First, the results showed that there was no statistically significant association between global self-esteem and alcohol use ($\rho = -0.191$; $p = .052 > .05$), indicating a low-magnitude inverse trend that did not reach statistical significance.

When the specific dimensions of self-esteem were analyzed, relevant differences were identified. Personal self-esteem showed a significant inverse association of low magnitude with alcohol use ($\rho = -0.215$; $p = .029 < .05$), suggesting that higher levels of personal self-worth were associated with lower alcohol use. Similarly, school-academic self-esteem showed a significant inverse association, of somewhat greater magnitude, with alcohol use ($\rho = -0.292$; $p = .003 < .01$), indicating that performance and positive self-appraisal in the school domain may function as protective factors against drinking.

By contrast, no statistically significant associations were found between alcohol use and social self-esteem ($\rho = -0.086$; $p = .386 > .05$) or family self-esteem ($\rho = -0.179$; $p = .069 > .05$), indicating that these dimensions did not directly influence drinking behavior in the population assessed.

Taken together, the results show that alcohol use among the students assessed was significantly associated only with certain specific dimensions of self-esteem, particularly those related to personal self-worth and the school domain, whereas global self-esteem and the social and family dimensions did not show significant associations.

Based on these findings, the general hypothesis was rejected because no statistically significant association was found between global self-esteem and alcohol use. However, the specific hypotheses were partially supported, given the presence of significant inverse associations between alcohol use and the personal self-esteem and school-academic self-esteem dimensions. By contrast, the specific hypotheses related to social self-esteem and family self-esteem were rejected because no statistically significant associations were observed.

Discussion

The findings of the present study suggest that alcohol use during adolescence is associated with specific psychological factors, which is consistent with recent scientific evidence. In particular, the results show that some dimensions of self-esteem are associated with alcohol use, whereas global self-esteem does not show a statistically significant association. This pattern suggests that alcohol use at this stage may be linked less to a broad psychological construct than to specific aspects of personal self-evaluation, as suggested in previous studies on adolescent vulnerability profiles (Castelli et al., 2022).

The absence of a significant association between global self-esteem and alcohol use may be interpreted in light of studies suggesting that broad self-esteem measures can conceal meaningful internal differences when analyzed in aggregate form. In this regard, longitudinal research has shown that adolescents with greater emotional distress may turn to alcohol as a coping strategy regardless of their overall self-evaluation, especially when internalizing symptoms such as anxiety or depression are present (Gohari et al., 2023). This perspective helps explain why global self-esteem did not emerge as a direct predictor of alcohol use in the present study.

When the specific dimensions were examined, the significant inverse association between personal self-esteem and alcohol use became especially relevant. A positive personal evaluation appears to strengthen adolescents' capacity to make adaptive decisions and resist social pressure, thereby reducing the likelihood of turning to alcohol in response to stressful situations. Similar findings have been reported in recent research highlighting perceived personal competence as a protective factor against adolescent risk behaviors (Pereira et al., 2025).

Likewise, the inverse association observed between school-academic self-esteem and alcohol use suggests that the educational setting plays an important role in the regulation of risk behavior. A sense of academic achievement and a positive appraisal of school performance may reinforce adolescents' commitment to medium- and long-term goals, thereby decreasing the probability of engaging in problematic drinking patterns. This interpretation is consistent with studies indicating that academic stress and school adjustment difficulties increase the risk of alcohol use when emotional resources are insufficient (Sharma et al., 2022).

The absence of statistically significant associations between alcohol use and the social and family dimensions of self-esteem suggests that these domains did not directly influence drinking behavior in the population studied. This result may be explained by the role of external contextual factors, such as social norms and cultural models, which may shape the influence of social and family relationships

on adolescent behavior. In socially vulnerable settings, alcohol use may persist even when social and family ties remain relatively stable, as suggested by research conducted in Latin American populations (Monzon et al., 2024).

From a population-level perspective, the findings are also consistent with recent data showing the persistence of alcohol use among secondary school students despite preventive efforts developed in school settings. This highlights the need to strengthen prevention strategies from a psychological perspective by prioritizing the development of personal resources such as self-esteem and emotional regulation, beyond interventions based exclusively on information provision (Hoots et al., 2023). These findings should nevertheless be interpreted in light of the limitations of the cross-sectional design and the use of self-report instruments. Even so, they reinforce the importance of psychosocial interventions aimed at strengthening psychological well-being and reducing harmful alcohol use among adolescents (Belay et al., 2024).

CONCLUSIONS

The present study suggests that alcohol use during adolescence is a complex behavior influenced primarily by specific psychological factors rather than by general self-evaluation alone. The results showed that global self-esteem was not significantly associated with alcohol use. However, the dimensional analysis indicated that particular areas of self-esteem did play a relevant role in this behavior.

In particular, personal self-esteem was inversely and significantly associated with alcohol use, suggesting that a positive self-appraisal may function as a protective factor against risk behaviors. Adolescents with a favorable perception of themselves may have greater resources for coping with social pressure and making adaptive decisions, thereby reducing the likelihood of resorting to alcohol as a coping strategy.

Likewise, the inverse association identified between school-academic self-esteem and alcohol use highlights the importance of the educational context in the regulation of risk behaviors. A positive appraisal of academic performance and a sense of school achievement may strengthen commitment to personal and educational goals, thereby decreasing vulnerability to alcohol use. In this sense, the school may play an important role in promoting adolescent psychological well-being.

By contrast, the social and family dimensions of self-esteem did not show significant associations with alcohol use, suggesting that these domains did not directly influence this behavior in the sample studied. This finding may be explained by the presence of sociocultural and contextual factors that moderate the

influence of social and family relationships, especially in socially vulnerable settings.

From a preventive standpoint, the findings underscore the need to implement comprehensive strategies that go beyond traditional information-based approaches and focus on strengthening psychological resources such as self-esteem, emotional regulation, and coping skills. Although the results should be interpreted in light of the limitations of the cross-sectional design and the use of self-report instruments, the evidence obtained provides relevant information for the educational context analyzed and supports the importance of continuing to investigate this issue through preventive and longitudinal approaches.

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TEACHING STRATEGIES AND DEVELOPMENT OF ORAL EXPRESSION IN STUDENTS AT THE ANDRÉS BELLO INSTITUTE OF HIGHER EDUCATION – PUNO

Arcaya Florez, Mijhu

ABSTRACT

The objective of this research was to determine the influence of teaching strategies on the development of oral expression in students at the Andrés Bello Higher Education Institute in Puno during the 2025 academic year. The study was quantitative, descriptive-correlational in nature, with a non-experimental, cross-sectional design. The population consisted of students from the Institute, and the sample consisted of 106 students selected through non-probabilistic convenience sampling. The technique used was a survey, and the instrument was a structured questionnaire with a five-point Likert scale, consisting of 30 items distributed across two variables. Validity was determined by expert judgment, and reliability reached a Cronbach's alpha coefficient of 0.92, indicating high internal consistency. The descriptive results show that 55.7% of students perceive an average level in the application of teaching strategies, and 58.5% have an average level of oral expression. Inferential analysis using Pearson's correlation showed a high and significant positive relationship between both variables ($r = 0.81$; $p < 0.01$). It is concluded that teaching strategies significantly influence the development of students' fluency, coherence, pronunciation, and communicative confidence, constituting a determining factor in initial teacher training in intercultural contexts.

Keywords: teaching strategies; oral expression; communicative competence; active methodology.

INTRODUCTION

Oral expression is a structural competence in teacher training, since the educational act is essentially based on communication. Pedagogical practice involves arguing, explaining, guiding, providing feedback, and generating ongoing dialogue with students; therefore, the quality of teacher discourse directly affects the construction of learning. From an epistemological perspective, language is not only a means of transmitting information, but also an instrument of cognitive

mediation that enables the cognitive organization of thought and the construction of shared meanings. In this sense, strengthening oral expression in initial teacher training becomes an academic and professional necessity.

From a sociocultural perspective, Vygotsky (1978) argues that the development of higher psychological processes occurs through social interaction mediated by language. Speech plays a regulatory role in thought and is the main vehicle for conceptual internalization. In line with this perspective, Bruner (1996) asserts that learning is constructed through dialogue and the negotiation of meanings, highlighting the role of communication in the formation of complex cognitive structures. These theoretical positions allow us to understand that oral competence is not an accessory component, but rather a central axis of intellectual development.

For his part, Hymes (1972) expanded the traditional concept of linguistic competence to include communicative competence, integrating sociocultural, pragmatic, and contextual dimensions of language. This theoretical expansion is fundamental in intercultural contexts such as the Puno highlands, where the interaction between languages and cultures influences students' communicative confidence and performance.

From the perspective of educational psychology, Ausubel (2002) argues that meaningful learning occurs when new knowledge is substantively related to previous cognitive structures. In this process, verbalization plays an organizing role in thinking, allowing students to structure and consolidate ideas. Complementarily, Piaget (1964) argues that cognitive development involves processes of assimilation and accommodation that are evident in the ability to express ideas logically and coherently.

Internationally, UNESCO (2023) emphasizes that strengthening communication skills is an essential component of ensuring inclusive, quality education. Recent studies in higher education indicate that active methodologies significantly increase oral participation and communication confidence in university students. This research highlights that traditional teacher-centered instruction limits discursive interaction and reduces opportunities for communication practice.

In Latin America, Cassany (2012) argues that traditional language teaching favors repetition and memorization, neglecting the active construction of academic discourse. In his analysis, he argues that oral competence requires spaces for systematic practice where students can argue, debate, and reflect critically. Empirically, Cordero (2022) found that the application of structured debates in pedagogical institutes generated significant improvements in argumentative coherence and stage confidence.

In the Peruvian context, Cutipa (2020) found a significant positive correlation ($r = 0.72$) between the implementation of active methodologies and the development of verbal fluency in university students in the south of the country. Similarly, Mamani (2021), in a study conducted at the National University of the Altiplano, determined that sociolinguistic factors influence the communicative confidence of bilingual Quechua-Spanish and Aymara-Spanish students, highlighting the need for contextualized pedagogical strategies.

Quispe (2022) identified that the predominance of traditional expository methodologies reduces active oral participation and limits the development of argumentative skills. Similarly, research published in Latin American scientific journals reports that the absence of participatory strategies negatively impacts communicative confidence and the logical structuring of discourse.

At the regional level, teacher training in the Puno highlands faces additional challenges related to cultural diversity, bilingualism, and traditional pedagogical practices. Preliminary observations at the Andrés Bello Higher Pedagogical Education Institute show that a considerable percentage of students have difficulties in organizing discourse, using formal language appropriately, and managing stage presence during academic presentations and pre-professional practices.

This situation reveals a gap between the curricular requirements of teacher training and the actual level of communicative competence achieved by students. Consequently, it is pertinent to scientifically analyze the relationship between the teaching strategies implemented and the development of oral expression in order to generate empirical evidence to support institutional methodological improvements.

In line with the above, the research poses the following question: How do teaching strategies influence the development of oral expression in students at the Andrés Bello Higher Education Institute of Pedagogy in Puno?

The general hypothesis is that teaching strategies significantly influence the development of students' oral expression.

This research is theoretically relevant in that it strengthens the conceptual framework on communicative competence in teacher training; methodologically relevant in that it applies valid and reliable instruments; and socially relevant in that it contributes to improving educational quality in high Andean intercultural contexts.

METHOD

Research Design

The study adopted a quantitative, descriptive-correlational approach, with a non-experimental, cross-sectional design, carried out during the 2025 academic year at the Andrés Bello Higher Pedagogical Education Institute in Puno. This design allows for the description of the variables "teaching strategies" (participatory, collaborative, and metacognitive) and "oral expression" (verbal fluency, coherence/discursive organization, and confidence/stage presence), as well as the analysis of their relationship without experimental manipulation (Hernández-Sampieri et al., 2014; Ávila, 2023).

Participants

The population consisted of students from the Andrés Bello Higher Pedagogical Education Institute in Puno. The sample included 106 students, selected through non-probabilistic convenience sampling, a technique suitable for exploratory studies in accessible educational contexts where the availability of participants is key (Etikan et al., 2016).

Instruments

A survey was used as the data collection technique, and a structured five-point Likert-type questionnaire was used as the main instrument, consisting of 30 items distributed across the two independent variables. Content validity was determined by expert judgment, and reliability reached a Cronbach's alpha coefficient of 0.92, indicating high internal consistency (Cronbach, 1951).

Procedure and Data Analysis

The analysis incorporated descriptive statistics (frequencies, percentages, and levels: high, medium, low) to characterize the variables, and Pearson's correlation to evaluate the relationship between them, with a significance level of $\alpha = 0.05$ ($p < 0.05$). All procedures were performed with standard statistical software, ensuring reproducibility (Field, 2018).

RESULTS

For a more in-depth analysis, both variables were broken down into dimensions:

Variable 1: Teaching strategies — D1: Participatory strategies; D2: Collaborative strategies; D3: Metacognitive strategies.

Variable 2: Oral expression — D1: Verbal fluency; D2: Coherence and discourse organization; D3: Confidence and stage presence.

The sample consisted of 106 students.

1. Variable: Teaching Strategies

Table 1

Level of teaching strategies (general)

Level	Frequency	%
High	30	28.3
Medium	59	55.7
Low	17	16.0
Total	106	100

Source: Own elaboration.

It can be seen that 55.7% perceive an average level in the application of teaching strategies. Only 28.3% consider the level to be high, which shows a predominance of partially active methodological practices.

Table 2

Dimension 1: Participatory strategies

Level	Frequency	%
High	34	32.1
Medium	51	48.1
Low	21	19.8
Total	106	100

Source: Own elaboration.

The average level predominates (48.1%), indicating that the use of debates, dialogued presentations, and brainstorming is implemented moderately.

Table 3

Dimension 2: Collaborative strategies

Level	Frequency	%
High	29	27.4
Medium	57	53.8
Low	20	18.8
Total	106	100

Source: Own elaboration.

53.8% report an average level, suggesting that teamwork and cooperative learning are not yet fully established.

Table 4

Dimension 3: Metacognitive strategies

Level	Frequency	%
High	26	24.5
Medium	60	56.6
Low	20	18.9
Total	106	100

Source: Own elaboration.

There is a predominance of the average level (56.6%), indicating limited promotion of reflection on the communication process itself.

2. Variable: Oral Expression

Table 5

General level of oral expression

Level	Frequency	%
High	29	27.4
Medium	62	58.5
Low	15	14.1
Total	106	100

Source: Own elaboration.

58.5% have an average level, which shows that most have acceptable oral skills, but there is still room for improvement.

Table 6

Dimension 1: Verbal fluency

Level	Frequency	%
High	31	29.2
Medium	56	52.8
Low	19	18.0
Total	106	100

Source: Own elaboration.

The average level predominates (52.8%), showing frequent pauses and limitations in discursive spontaneity.

Table 7

Dimension 2: Discourse coherence and organization

Level	Frequency	%
High	27	25.5
Medium	63	59.4
Low	16	15.1
Total	106	100

Source: Own elaboration.

59.4% are at the intermediate level, indicating partial difficulties in the logical structuring of ideas.

Table 8

Dimension 3: Confidence and stage management

Level	Frequency	%
High	24	22.6
Medium	61	57.5
Low	21	19.9
Total	106	100

Source: Own elaboration.

The average level predominates (57.5%), reflecting nervousness and limited mastery of body language.

3. Inferential Analysis by Dimensions

Pearson's correlation was applied to determine the relationship between dimensions.

Table 9

Correlation between main dimensions

Related dimensions	r	p
Participative – Fluidity	0.76	0.000
Collaborative – Coherence	0.79	0.000
Metacognitive – Security	0.74	0.000
Teaching strategies (overall) – Oral expression (overall)	0.81	0.000

Source: Own elaboration.

The results show high and statistically significant positive correlations ($p < 0.01$). This indicates that the greater the application of teaching strategies, the greater the development of oral expression.

The highest correlation is between collaborative strategies and discursive coherence ($r = 0.79$), which shows that teamwork promotes the logical structuring of discourse.

Comprehensive Interpretation of Results

The average level predominates in all dimensions, highlighting the need for methodological reinforcement.

Participatory strategies directly influence verbal fluency.

Collaborative strategies enhance discursive organization.

Metacognitive strategies improve communicative confidence.

The general hypothesis is confirmed by finding a high correlation ($r = 0.81$).

CONCLUSIONS

A high and statistically significant positive relationship was found between teaching strategies and the development of oral expression ($r = 0.81$; $p < 0.01$). This result empirically confirms that the methodological quality implemented in the classroom is a determining factor in strengthening communication skills in initial teacher training.

The predominance of the average level in both variables shows an intermediate situation of pedagogical development, characterized by the partial application of active methodologies and by acceptable but not consolidated communicative performance. This condition reveals the existence of a gap between the curricular requirements of the professional teaching profile and the actual level of competence achieved by students.

The analysis by dimensions identified that collaborative strategies are more closely associated with coherence and discursive organization, demonstrating that group interaction favors the logical structuring of verbal thought. Likewise, participatory strategies are directly linked to fluency, while metacognitive strategies affect confidence and stage management.

The results suggest that the development of oral expression does not depend exclusively on individual skills, but rather on a pedagogical environment that promotes active participation, critical reflection, and systematic practice of academic discourse.

From an educational perspective, the research shows that the systematic implementation of active teaching strategies not only improves immediate communicative performance but also strengthens professional skills that are essential for teaching in intercultural contexts such as the Puno highlands.

In academic terms, the findings provide empirical evidence that supports sociocultural and constructivist approaches to learning, confirming that structured pedagogical interaction significantly influences the consolidation of communicative competence.

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INVENTORY MANAGEMENT AND PROFITABILITY IN HARDWARE STORES IN THE CITY OF PUNO

Carrizales Quispe, Cristian Eduardo

ABSTRACT

The general objective of the research was to determine how inventory management and profitability are related in hardware stores in the city of Puno. Regarding the methodology, the study adopted a quantitative approach of a basic type, with a correlational level and a non-experimental cross-sectional design. The population consisted of fourteen companies in the hardware sector; since it did not represent a significant population, the total number of companies was considered as the sample, applying a non-probabilistic census and intentional sampling method under inclusion and exclusion criteria established by the researcher. The data collection technique was the survey, and a questionnaire composed of twelve Likert-scale items was used as the instrument to measure both variables. For data analysis, tabulations, charts, figures, and descriptive and inferential statistical methods were employed. Regarding the results, it was evidenced that 71.43 percent of the companies present a moderate level of inventory management, 21.43 percent show deficient management, and only 7.14 percent demonstrate efficient management. Likewise, 50.00 percent of the companies reported low profitability, 35.71 percent moderate profitability, and only 14.29 percent high profitability. In the conclusions, it was determined that deficient inventory management has a direct relationship with low levels of profitability, which limits the increase in net income, reinvestment in other assets, and the distribution of dividends.

Keywords: Management, inventories, profitability, assets, dividends.

INTRODUCTION

In the current context of business management, the efficient administration of inventories has become a fundamental element for the optimization of resources and the operational continuity of organizations. In this regard, Cardoso and Rodríguez (2020) argue that adequate inventory control makes it possible to reduce costs and strengthen the financial performance of companies. However, when

inventory management is inadequate, it generates additional costs, stockouts, and operational deficiencies that directly affect business profitability (Moreno et al. 2023).

This problem intensifies when organizations do not apply technical control procedures, which limits their ability to respond to demand and seriously compromises their financial results, as stated by (Espinal & Quispe, 2020). In this sense, the adoption of standardized methods for recording and monitoring inventories contributes to strengthening decision-making and improving business profitability, according to (Córdova et al. 2022).

From an operational perspective, efficiency in inventory management enables better organization of goods and products, directly and indirectly impacting manufacturing, commercial, and distribution companies by regulating the inflow and outflow of merchandise from warehouses (Paredes, 2021). However, inventory management continues to be a complex task in many organizations, affecting their sustainability and business success (Ticona, 2024).

At the international level, a study conducted in Kenya showed that deficient inventory control in the manufacturing sector contributed to a decline in economic performance, reflected in a reduction in Gross Domestic Product, which highlights the relevance of efficient management of these assets (Sonko & Akinlabi, 2020).

In the Peruvian context, inventory management represents a significant challenge for companies engaged in the commercialization of hardware products (Pizzán-Tomanguillo et al., 2022). Investment in inventories constitutes one of the most important items for this type of company, since the acquired goods are intended for resale and income generation (López & Mamani, 2024). In the hardware stores of the city of Puno, the absence of formal and updated inventory control systems leads to empirical purchasing decisions, accumulation of low-turnover products, and deficiencies in planning (Fuentes & Mancilla, 2022).

These practices generate negative economic repercussions, such as increased storage costs, capital immobilization, losses due to deterioration, and stockouts, directly affecting business profitability (Apaza & Chura, 2021). Likewise, according to Gutiérrez (2022), the lack of key management indicators, such as inventory turnover, reorder point, and service level, limits strategic planning capacity and reduces business competitiveness.

From an organizational standpoint, these deficiencies negatively affect managerial decisions and the overall performance of the company (Moreira-Cañarte and Peñafiel-Rivas, 2019). Similarly, inaccurate inventory information compromises decision-making at all levels, increasing financial and operational

risks (Flores, 2021). In response to this situation, strengthening internal controls, training personnel, and standardizing purchasing and storage policies are presented as viable alternatives to improve operational efficiency and profitability (Pérez, 2024).

Various studies recognize that business profitability does not depend solely on financial or commercial decisions, but also on the strength of the operational processes that support business activity (Vásquez, 2024). In the hardware sector, the way inventories are organized, controlled, and optimized directly affects economic performance and the sustainability of profit margins (Lizcano, 2024). Nevertheless, traditional practices and limited specialization in modern inventory control techniques persist, revealing an operational and technical gap that restricts business growth (Bambaren et al., 2022).

METHOD

Given that the research method consists of a series of ordered and systematic steps that make it possible to obtain and analyze data in order to respond to a hypothesis or solve a research problem (Hinojosa et al., 2024), the present study was developed under a quantitative approach, since it seeks to measure, explain, and objectively verify the phenomena under study through the use of numerical data (Hernández-Sampieri et al., 2014). Furthermore, a non-experimental cross-sectional design with a correlational scope was employed, in order to establish the degree of relationship, whether positive, negative, or null (Ñaupas et al., 2014).

The study was supported by the hypothetical-deductive method, since it sought to empirically test the relationship between variables without manipulating them. This methodological choice not only allows the interpretation of phenomena as they occur in their real context, but also provides scientific rigor to the analysis, enabling a more precise and reasoned understanding of how the factors under study interact within business dynamics.

The study context comprised fourteen hardware stores in the city of Puno during the 2024 commercial period. Given that the units of observation were not numerous, the total number of companies was rigorously considered as the population and, through census sampling, the entire group was taken as the sample by decision of the researcher.

Only the following were included: a) micro and small enterprises, b) those with legal status, and c) those willing to participate. Companies that did not meet the inclusion criteria were excluded.

The data collection technique used in this research was the survey, while the instrument applied was the questionnaire, due to its relevance for obtaining

quantifiable information in quantitative studies. In this regard, Cruz del Castillo et al. (2014) state that the survey allows the systematic collection of data regarding perceptions, behaviors, and characteristics of a given population, facilitating the statistical analysis of the study variables.

Accordingly, a structured questionnaire was developed, composed of items formulated as statements, so that respondents could express their level of agreement or disagreement, which made it possible to objectively measure the variables inventory management and profitability. Likewise, the use of Likert-type scales is appropriate when evaluating attitudes, practices, and levels of organizational performance, since it enables the standardization of responses and improves the reliability of the results obtained (Vara-Horna, 2010).

The questionnaire was administered directly, ensuring that participants adequately understood each item, with the purpose of minimizing bias and interpretation errors (Hinojosa et al., 2024), as recommended by authors in social and business research.

The study was developed through descriptive statistical techniques, which are responsible for organizing, summarizing, and presenting the data obtained in a research study in a clear and systematic manner (Proaño, 2020). Descriptive statistics were analyzed through tables.

On the other hand, inferential statistics were applied, which involve the use of probabilistic methods that allow generalizations, estimations, and predictions about an entire population (Ticona, 2024). Subsequently, the relationship between inventory management and profitability was examined through quantitative analysis, which allowed the empirical testing of the hypotheses and the evaluation of their significance. This method seeks to guarantee scientific rigor and the validity of the findings.

RESULTS AND DISCUSSION

According to Vara-Horna (2010), reliability can be verified through different statistical methods, the most widely known being Cronbach's Alpha, which is used for quantitative instruments.

Table 1

Inventory management

	Frequency	Percentage	Valid percentage	Cumulative percentage
Deficient	3	21,4	21,4	21,4
Regular	10	71,4	71,4	92,9
Valid Efficient	1	7,1	7,1	100,0
Total	14	100,0	100,0	

Note. Survey processed in IBM SPSS 25.

Table 1 presents the data obtained after processing the information. It can be observed that 71.43 percent of the companies analyzed through the applied instrument report that their inventory management, considered the main study variable, is at a moderate level.

Meanwhile, 21.43 percent indicated that their management operates at a deficient level, and only 7.14 percent reach an efficient level of performance.

Table 2

Profitability

	Frequency	Percentage	Valid percentage	Cumulative percentage
Deficient	7	50,0	50,0	50,0
Regular	5	35,7	35,7	85,7
Valid Efficient	2	14,3	14,3	100,0
Total	14	100,0	100,0	

Note. Survey processed in IBM SPSS 25.

Table 2 illustrates the results obtained regarding the profitability variable. Fifty-point zero percent, that is, half of the companies under study, stated that their profitability is low. Those that consider their profitability to be moderate represent 35.71 percent of the total.

For their part, a small proportion of 14.29 percent affirmed that their profitability is high; however, these results demonstrate that the projected benefits are not being achieved.

Table 3

Return on assets

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Deficient	9	64,3	64,3	64,3
	Regular	4	28,6	28,6	92,9
	Efficient	1	7,1	7,1	100,0
	Total	14	100,0	100,0	

Note. Survey processed in IBM SPSS 25.

When analyzing Table 3, it is observed that, regarding the return on assets in the companies assessed through the instrument, only 7.14 percent of the total stated that their return on assets is high. On the other hand, 28.57 percent indicated that they maintain a moderate return on their assets. Finally, 64.29 percent reported that their return on assets is low. These results reveal that the returns on investments are not adequate.

In this sense, research in the social sciences often seeks to go beyond merely describing the distribution of variables; it aims to test hypotheses and extrapolate the results obtained from the sample to the population or universe (Cruz del Castillo et al., 2014).

DISCUSSION

The empirical evidence supports the relationship between inventory management and profitability. It was concluded that there is a significant and positive relationship between both variables, highlighting that better inventory management practices favorably influence financial results.

Similarly, Delgado (2023) demonstrated that deficient policies and errors in inventory records negatively affect return on assets, gross margin, and net profit margin. Likewise, Huamanlazo and Palma (2023) confirmed the existence of a direct, moderate, and significant relationship between inventory management and profitability, while Yaranga (2022) identified that deficient inventory management increases cost of sales and reduces profitability levels in the analyzed hardware companies.

Regarding the findings of Obeidat (2021), these show a positive and significant association between inventory turnover and profitability indicators, namely return on assets and gross margin. These findings are consistent with the results obtained in the present study and in previous research indicating that higher turnover reduces

storage and obsolescence costs, allowing resources to be reassigned to income-generating activities.

By applying Spearman's Rho correlation coefficient to test the general hypothesis that inventory management is related to profitability in hardware companies, the data shows a Rho with a calculated p-value of 0.019, which is lower than 0.05, and a moderate positive correlation of $r = 0.616$. According to statistical interpretation, inventory management is significantly related to profitability; that is, there is a direct association: the more efficient the inventory management, the higher the profitability.

These results are similar to those determined by Ramírez (2022), who also applied Spearman's Rho and obtained a p-value of 0.000, lower than 0.05, confirming that inventory management is positively related to profitability in a hardware company. Additionally, the reported Rho value was $r = 0.777$, indicating a very strong positive correlation between the variables.

From another perspective, if the objective is to achieve efficient inventory management, López and Mamani (2024) demonstrated, through a p-value of 0.000 lower than 0.05, that there is a positive relationship between internal control and inventory management. With a Rho index of $r = 0.921$, both variables present a very high degree of correlation, indicating that internal control is effectively aligned with inventory management and contributes to improved profitability.

In line with the comparison of results, Huamanlazo and Palma (2023), regarding net profit margin as a measure of profitability, obtained a p-value of 0.024, lower than 0.05, validating the alternative hypothesis and affirming that inventory control management is significantly related to profit margin. The correlation coefficient of $r = 0.644$ established a moderate relationship between both variables in a hardware company.

Continuing with the comparison process, the present study shows a Rho of $r = 0.651$, indicating a moderate positive correlation between inventory reception and profitability. Delgado (2023), in contrast, obtained a Rho of $r = 0.372$, representing a low direct correlation in a specific company, differing proportionally from the results obtained in this research. Furthermore, a significance value of 0.035 was calculated, demonstrating the existence of a positive association between optimal inventory reception and profitability.

In the case of the hardware companies analyzed in this study, a calculated p-value of 0.012 was obtained, leading to the rejection of the null hypothesis and the acceptance of the alternative hypothesis; therefore, there is a significant relationship between inventory reception and profitability. Although similarities can be

observed between the findings of both studies, internal and external factors must be considered, as they may modify the scenario reflected in the results.

Regarding inventory storage, a calculated p-value of 0.038 was obtained, which is lower than 0.05; therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted, clearly indicating that inventory storage is significantly related to profitability in these hardware companies. Additionally, a Rho of $r = 0.559$ was obtained; that is, there is a moderate direct correlation of 55.9 percent between inventory storage and profitability.

These results are compared with those presented by Gutiérrez (2022), who, through Spearman's Rho statistic, found a calculated p-value of 0.017, rejecting the null hypothesis and coinciding with the decision of this study. Likewise, a Rho of $r = 0.432$ was obtained, meaning that 43.2 percent of storage is related to profitability in grocery companies, differing from the 55.9 percent obtained in this research. This difference may be explained by the fact that the companies belong to different commercial sectors and realities.

Subsequently, when testing whether there is a relationship between inventory distribution and profitability, the results are compared with those obtained by Yaranga (2022), who analyzed distribution costs and their relationship with return on equity in food sector companies listed on the Lima Stock Exchange. In that study, Pearson's correlation coefficient was $r = -0.536$, indicating a negative correlation between distribution costs and return on equity; that is, as distribution costs increase, profitability decreases.

In contrast, in the present research, when determining the relationship between inventory distribution and profitability in hardware companies, a Rho of $r = 0.655$ was found, statistically affirming that 65.5 percent of inventory distribution is directly and moderately correlated with the profitability of the analyzed companies.

On the other hand, Flores (2021), by applying Spearman's Rho, demonstrated a relationship between internal control and inventory distribution at the Essalud Hospital, obtaining a Rho of $r = 0.829$, which represents a high correlation between the variables, with a calculated p-value of 0.000 lower than 0.05, rejecting the null hypothesis and accepting the alternative hypothesis.

CONCLUSIONS

The present study demonstrates that inventory management constitutes a determining factor in the success or failure of companies that maintain significant investments in inventories. In this sense, efficient inventory management directly influences resource optimization, cost reduction, and consequently, sustained improvement in business profitability.

From another analytical perspective, ensuring compliance with quality standards, accuracy in requested quantities, and timely updating of records will sustain a favorable and direct relationship with profitability.

Therefore, by strategically prioritizing this activity, storage costs will be optimized and its positive impact on profitability will be strengthened. Likewise, improvements in delivery cycles, picking processes, and inventory transportation management will consolidate favorable and sustainable results in the generation of economic benefits for companies.

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ICT IN HOSPITAL MANAGEMENT AND CARE: USE BY HEALTHCARE AND ADMINISTRATIVE STAFF AT THE JULIACA HOSPITAL

Chambi Quispe, Karla Jakelyny

ABSTRACT

This article analyzes the use of Information and Communication Technologies (ICT) in hospital management and care, specifically among the clinical and administrative staff of the Juliaca Hospital, with the aim of identifying their level of application, benefits, and limitations in institutional processes. This research employed a quantitative approach, as it allowed for the collection and analysis of numerical data related to the use of ICT in hospital management and care. Through the application of structured instruments, such as surveys administered to clinical and administrative staff, measurable data were obtained and processed using statistical techniques, primarily frequencies and percentages, which facilitated an objective interpretation of the results. Furthermore, the study was descriptive in nature, as it focused on describing the characteristics, conditions, and level of ICT use within the hospital context, without manipulating variables. The research sought to detail how staff use technological tools in their daily activities, identifying strengths and limitations in their application. This level of analysis allowed for a clear and precise understanding of the studied reality, based on observation and systematic analysis of the data obtained. The results showed that most staff members use ICT in their daily activities, primarily for recording clinical information, managing appointments, preparing reports, and internal communication. However, some limitations were identified related to insufficient training, system failures, and limited technological updates. Despite these challenges, the use of ICT has significantly contributed to improving information organization, reducing wait times, and optimizing administrative processes. In conclusion, ICT represents a strategic resource for strengthening management and hospital care at the Juliaca Hospital. Its proper implementation improves service quality, optimizes internal processes, and contributes to patient-centered care. However, to maximize its benefits, it is essential to invest in training, infrastructure, and an organizational culture focused on innovation and continuous improvement.

Keywords: Information and Communication Technologies (ICT), Hospital management, Healthcare, Healthcare staff, administrative staff.

INTRODUCTION

Digital transformation has emerged as a strategic pillar for strengthening health systems worldwide. Rapid technological development and the growing demand for healthcare services have driven the need to modernize clinical and administrative processes through the incorporation of Information and Communication Technologies (ICT). According to the World Health Organization (WHO, 2020), digital health is an essential component for achieving universal health coverage, improving the quality of care, and ensuring equitable access to services.

The Pan American Health Organization (PAHO, 2021) maintains that the digitization of the health sector in the Americas strengthens health governance, improves operational efficiency, and optimizes resource management. In this context, health information systems become strategic tools for data-driven decision-making, epidemiological monitoring, and public policy evaluation.

In Peru, the digital transformation process is supported by a robust regulatory framework. The Ministry of Health (MINSA, 2019) established guidelines for the implementation of health information systems that aim to standardize processes and ensure the quality of clinical records. Subsequently, MINSA (2020) approved the Technical Health Standard for Electronic Health Records, promoting the progressive digitization of clinical documentation and strengthening information security.

In Latin America, Luna (2020) highlights that health information systems strengthen health planning and improve epidemiological management. In Peru, Vargas (2022) and Vásquez (2022) demonstrate that the incorporation of ICT in hospitals contributes to administrative efficiency, indicator monitoring, and the optimization of human resources.

The Juliaca Hospital, as a regional public referral institution, faces the challenge of integrating digital technologies within a context of budgetary constraints and high demand for care. The proper use of tools such as electronic health records, statistical registration systems, and administrative platforms is essential to guarantee safe, timely, and high-quality care. In this context, the need arises to analyze the use of ICT by the healthcare and administrative staff of the Juliaca Hospital, evaluating their level of implementation, perception, and utilization. Identifying gaps will allow for the proposal of strategies aimed at institutional strengthening and the continuous improvement of health services.

METHOD

Research Approach, Level, and Design

This research employed a quantitative approach, as it focused on the objective measurement of Information and Communication Technology (ICT) use among administrative and healthcare staff through the collection and analysis of numerical data. According to Hernández-Sampieri and Mendoza (2018), the quantitative approach allows for the description, explanation, and prediction of phenomena based on statistical analysis, ensuring objectivity and scientific rigor. In this study, this approach was appropriate because it sought to measure levels of use, frequency, digital skills, and differences between groups.

The study was descriptive in nature, as its purpose was to identify and characterize the level of ICT use among staff at the Juliaca Hospital. According to Arias (2016), descriptive research focuses on specifying properties, characteristics, and profiles of people, groups, or phenomena, without manipulating variables. In this case, the digital practices of administrative and healthcare staff were described within their actual work context.

Furthermore, the research employed a quasi-experimental design, as it worked with existing groups (administrative and healthcare staff) without random assignment, but still allowing for comparison between them. According to Campbell and Stanley (1963), quasi-experimental designs are used when it is not possible to fully manipulate the independent variables or perform random assignment, but the aim is to analyze potential effects or differences between groups. In this study, the levels of ICT use were compared between the two work groups, which justifies the adoption of this design.

Population and Sample

Population

The population consisted of all administrative and healthcare staff at the Juliaca Hospital during the study period. This population included healthcare professionals (physicians, nurses, obstetricians, technicians) and administrative staff (statistics, admissions, records, logistics, human resources, among others).

According to Tamayo and Tamayo (2004), the population is the total set of individuals who share common characteristics about which information is desired. In this study, the common characteristic was performing work functions at the hospital and using technological tools in their daily activities.

Sample

A stratified probability sample was used, considering two strata:

- Healthcare staff
- Administrative staff

The choice of stratified sampling is based on the findings of Hernández-Sampieri and Mendoza (2018), who indicate that this type of sampling is appropriate when the population has clearly differentiated subgroups and it is desired to ensure proportional representation of each. In this case, the division between administrative and healthcare staff constitutes a relevant structural distinction for the comparative analysis.

The use of this sample was justified because it:

- Allowed for an objective comparison of the level of ICT use between both groups.
- Guaranteed proportional representation.
- Reduced selection bias.
- Improved the statistical precision of the results.

RESULTS

1. Sociodemographic characteristics of the sample

Table 1

Distribution according to age.

Labor Group	frequency (n)	Percentage (%)
healthcare staff (appointed + cas)	1020	29.41%
administrative staff (appointed + cas)	212	70.67%

Source: Own elaboration

Model interpretation:

It is observed that 29.41% of the staff belong to the healthcare group and 70.67% to the administrative group.

This distribution shows that the sample has a higher representation of administrative staff. However, both groups have a sufficient number of participants to allow for valid statistical comparisons. The difference in proportions may influence institutional dynamics, since administrative staff are typically directly involved in the systematic use of digital platforms, registration systems, and computer processes.

2. Distribution by age

Table 1

Distribution by age.

Age range	Frequency	Percentage (%)
20–30 years	122	10%
31–40 years	240	19%
41–50 years	520	42%
>50 years	350	28%
Total	1232	100%

Source: Own elaboration

Model interpretation:

The largest percentage of staff are in the 41–50 age range (42%), followed by the over-50 age group (28%). Only 10% are in the 20–30 age range.

This indicates that the workforce is predominantly mature adults. This is relevant because the literature suggests that age can influence digital skills, as younger generations tend to be more familiar with technological tools. Therefore, the age composition could be associated with the levels of ICT use observed.

3. Level of TIC use

Table 3

General level of ICT use

Level	Frequency	Percentage (%)
Low	850	68.99%
Half	250	20.29%
High	80	6.49%
Very high	52	4.22%

Source: Own elaboration

Model interpretation:

68.99% of staff have a low level of ICT use, while only 6.49% reach a high level and 4.22% a very high level.

These results show that the use of digital technologies at the Juliaca Hospital is predominantly limited. Most staff do not use ICT in an advanced or strategic way, which could be related to factors such as lack of training, resistance to change, limitations in technological infrastructure, or insufficient institutional implementation of digital tools.

This finding represents a significant gap compared to national guidelines for digitalization in health.

4. Comparison between healthcare and administrative staff

Table 4

Level of ICT use according to work group

Level	Healthcare (%)	Administrative (%)
Low	70%	61%
Half	19%	25%
High	10%	12%
Very high	1%	2%
	100%	100%

Source: Own elaboration

Model interpretation:

It is observed that administrative staff have a higher percentage at the high and very high levels (14%) compared to healthcare staff (11%). Likewise, the low level is more frequent among healthcare staff (70%) compared to administrative staff (61%).

This suggests that administrative staff have greater exposure to and frequent use of digital tools, likely due to functions related to statistics, billing, record-keeping systems, filing, and document management. In contrast, clinical staff may prioritize direct clinical activities, limiting their intensive use of more complex technological tools.

5. Statistical test (if you apply hypotheses)

Table 2

Comparison of means

Cluster	Average	p-value
Healthcare	1.42	
Administrative	1,545	0.03092

Source: Own elaboration

Model interpretation:

Administrative staff showed a slightly higher mean level of ICT use (1.545) compared to healthcare staff (1.420).

The t-test showed a statistically significant difference ($p = 0.03092 < 0.05$), indicating a significant difference between the two groups.

DISCUSSION

The results show that the overall level of ICT use at the Juliaca Hospital is predominantly low (68.99%). This finding contrasts with the international recommendations of the World Health Organization (2020), which promote digital transformation as a strategic axis for strengthening health systems.

Similarly, the Pan American Health Organization (2021) maintains that digitalization improves operational efficiency and evidence-based decision-making. However, the results show that significant gaps still exist in technology adoption within hospitals.

In Peru, the Ministry of Health has established regulations for the implementation of digital systems and electronic health records. However, the prevailing low level of ICT use suggests that regulatory implementation does not always translate into effective use in daily practice.

The significant difference found between healthcare and administrative staff aligns with the findings of García-Peñalvo (2020), who indicates that digital transformation involves differentiated organizational changes depending on job functions. Administrative staff, being more closely linked to systematized processes and digital records, exhibit a higher level of technology use.

On the other hand, the predominant age (41–50 years) could influence digital adaptation, as Sheikh (2021) points out, noting that continuous training is a determining factor to avoid technological underutilization.

Digital transformation at the Juliaca Hospital requires sustained investment in technological infrastructure, continuous training, and institutional leadership, in order to align hospital practice with international and national guidelines for modernizing the health system.

CONCLUSIONS

The overall level of Information and Communication Technology use at the Juliaca Hospital is predominantly low, highlighting a significant gap between the digital transformation guidelines promoted by the World Health Organization and the Pan American Health Organization and the institution's current practices. Most staff members do not use digital tools strategically or in an advanced manner.

There is a statistically significant difference in the level of ICT use between healthcare staff and administrative staff. The administrative group shows higher levels of use, which is directly related to their functions involving computer systems, digital records, billing, and document management.

The age composition of the workforce, predominantly between 41 and 50 years old and over 50, may influence the level of digital skills and adaptation to new technologies. This reinforces the need for differentiated continuing education programs based on job profile and generation.

Although the digitization process in Peru has regulatory support promoted by the Ministry of Health of Peru, effective implementation within the hospital still presents limitations related to technological infrastructure, connectivity, insufficient training and possible resistance to organizational change.

Digital transformation at Juliaca Hospital requires a comprehensive strategy that includes sustained investment in technology, strengthening institutional leadership, ongoing staff training, and continuous monitoring of digital system usage. Only through these actions will it be possible to optimize hospital management, improve the quality of care, and align with national and international healthcare modernization policies.

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EFFECTS OF EDUCATIONAL DEMAND ON THE ACHIEVEMENT OF COVERAGE TARGETS IN PUBLIC EARLY EDUCATION INSTITUTIONS IN THE PROVINCE OF PUNO, 2022–2024

Chique Aguilar, Delia

ABSTRACT

The objective of this paper is to examine the educational demand for early childhood education in the province of Puno during the period 2022–2024, in order to identify its impacts on the achievement of national and regional coverage targets at this educational level. Likewise, the study research the socioeconomic, cultural, and geographic factors that affect the educational supply and accessibility to early childhood education in the region. This research will provide a basis for formulating recommendations aimed at improving both the coverage and the quality of early childhood education. On the other hand, the educational supply in the country consists of the set of aspects and characteristics related to teaching that are made available for use within the framework of established regulations, in which direct actors participate, such as programs, schedules, and teachers, for the benefit of the users of the educational system. The methodology used involves the collection of panel data related to the variables for the period from 2022 to 2024. The population is composed of 207 public, school-based early childhood education institutions in the province of Puno. The research design applied in this study is a non-experimental longitudinal design. The results obtained show that the educational supply experienced a significant increase between 2022 and 2023, rising from 187 to 207 educational facilities. However, by 2024 a slight reduction (or stabilization) is observed, closing with 206 facilities due to the loss of a rural unit in the district of Platería. In contrast to the number of school facilities, the teaching staff showed sustained growth during the same period. It is concluded that educational supply and educational demand are closely related, since both allow for the calculation and planning of educational facilities, teachers, service personnel, administrative staff, and other resources, ideally determined by current demand. However, enrollment figures reveal that some institutions are overcrowded with students while others do not reach the minimum coverage required for optimal functioning, yet they remain authorized and operational due to the existing regulatory framework.

Keywords: Educational Supply, Educational Coverage, Educational Institutions

INTRODUCTION

Public policies have established clear goals to achieve universal coverage of early childhood education in the country. However, in the province of Puno, these goals have not been fully achieved due to several limitations in adequate educational infrastructure. In many rural and remote areas, schools lack the necessary resources to receive children efficiently. The infrastructure of many institutions is either in poor condition or completely insufficient, which negatively affects the quality of the educational service. There are also deficiencies in the provision of materials and pedagogical resources. Despite the availability of some educational materials (books, educational games, and teaching staff), inequalities persist in the distribution of resources. Additionally, high school dropout rates, combined with geographic and logistical factors, the dispersion of rural populations, as well as socioeconomic conditions, cultural factors, and local customs, create significant barriers.

“All girls and boys have access to early childhood care and development services and quality pre-primary education so that they are ready for primary education” (United Nations General Assembly, 2015).

The right to education should be understood as permanent access to quality learning throughout life, and not only as the schooling of children and young people. This comprehensive perspective recognizes education for people of all ages and contexts and links it directly with the right to information, culture, and scientific knowledge (UNESCO, 2022).

Alternative educational modalities have significantly contributed to expanding the coverage of public policies and early childhood care and education in different countries, promoting equity by prioritizing vulnerable populations and areas with limited access (Soto, 2022).

The Organic Law of Intercultural Education guarantees quality early childhood education through universal access, equity, and respect for cultural diversity (Aguilar et al., 2023).

The lack of appropriate infrastructure for early childhood education, particularly in rural and urban-marginal sectors of Ecuador, represents a significant challenge. To address this issue, it is essential for the State to promote public policies that ensure consistent and adequate financial resources for the construction and equipment of educational centers in areas with the greatest need (Zambrano-Villacis, 2024).

Currently, the concept of educational quality is understood from a systemic and multidimensional perspective with a sociocultural nature. This gives it a diversity

that goes beyond the quantitative approach, which focuses on aspects such as the creation of educational institutions, pedagogical resources, expansion of coverage, and access to the system, among others. Likewise, it also goes beyond the qualitative perspective, which addresses teaching–learning processes, pedagogical methodologies, and evaluation and self-evaluation systems. In this sense, quality in early childhood education implies a complex approach to responding to Early Childhood Care and Education (ECCE) in the Latin American context, where diverse ideological, pedagogical, and sociocultural perspectives converge, among others (Jimenes & Quintana, 2029).

At present, infrastructure deficiencies are reflected in an unequal distribution of educational services within the city, with certain sectors experiencing shortages due to the historical lack of planning for social infrastructure in areas of urban and population expansion. Likewise, spaces with obsolete physical infrastructure coexist with others that have undergone improvement and renovation processes (Carlos & Peña, 2020).

Public policies, together with the participation of specialists, teachers, and families, have enabled significant progress in Peru in expanding access to early childhood education. This progress is reflected in the increase in enrollment of four- and five-year-old children. However, the quality of this educational level still does not meet the minimum standards established at the international level (Huamani, 2020).

The province of Puno faces significant challenges related to the coverage and quality of early childhood education. Despite public policies implemented to ensure the universalization of education in the country, rural and high-Andean areas of Puno still experience limitations in the educational supply and access to early childhood education services. Insufficient school infrastructure, lack of trained personnel, and cultural and linguistic barriers may be negatively affecting the achievement of early childhood education goals in the region. The absence of precise and up-to-date information on the factors influencing the coverage of these goals represents an important gap that this research seeks to address, in order to better understand the elements that limit or promote access to this educational level in Puno.

In the context of the province of Puno, educational demand may be influenced by geographic and cultural factors. The large rural population, the presence of indigenous communities, and the socioeconomic characteristics of families have a considerable impact on parents' decisions to send their children to early childhood education.

Puno, due to its cultural and geographic diversity, requires specific policies and approaches to ensure quality and accessible education for all. Likewise, this study will contribute to the development of more effective public policies to improve both the coverage and the quality of early childhood education, a fundamental level for educational development. Educational demand is influenced by factors that vary according to the socioeconomic, cultural, and geographic characteristics of each region. Furthermore, some institutions have a larger number of students while others have fewer; some have newly built infrastructure, while others are older.

Enrollment shows sustained growth during the analyzed period, driven by the State's obligation to expand public and free education. However, inequalities in access and enrollment between rural and urban areas persist despite efforts to universalize early childhood education, reflecting deep sociocultural and economic gaps in the region (Lassalle et al., 2020).

It is essential in early childhood education to address not only the challenge of access and coverage but also to place significant emphasis on the quality of care provided to children, especially during the first six years of life. According to the theoretical review conducted, deficiencies have been identified in the design and implementation of quality evaluation systems for educational services aimed at early childhood, particularly those developed through non-conventional modalities (Blanco, 2007).

Coverage of goals in early childhood education refers to the extent to which objectives established by national and regional educational policies are achieved in terms of the enrollment and registration of children in the early education level. According to the National and Regional Education Plans (MINEDU, 2017), these goals include increasing the coverage rate in early childhood education, especially in rural and vulnerable areas, with a focus on equity. The main coverage indicators refer to the number of children enrolled in early childhood education in relation to the child population eligible for this level. In the province of Puno, achieving these coverage goals faces several challenges, such as the limited number of educational institutions in rural areas and migration caused by factors such as illegal mining or extreme poverty.

In conclusion, Zapata Aguirre, in relation to public investment, states that there is a positive correlation between public investment and early childhood education services in the Piura Region in 2021. The study obtained a Spearman's Rho coefficient of 0.847, indicating a strong relationship between public investment and its contribution to closing gaps in coverage and quality in early childhood education services. In other words, as the execution of public investment accelerates, early childhood education services improve (Zapata, 2021).

If education is considered an investment, then two scenarios must be taken into account: individual investment and institutional investment. The first refers to an investment made by households with the aim of obtaining future economic and non-economic benefits. The second refers to a public investment carried out by the government or by private initiatives. Each household will invest in the education of its members differently depending on its capacity, needs, and preferences. Thus, each household will receive a relatively different level of education according to the amount spent.

In this sense, household spending on education can serve as an indicator whose inequalities represent the differences among the population that continues studying. Therefore, this variable was selected for the analysis of this group. According to the National Household Survey (ENAH), education expenditures include school uniforms, footwear, books, textbooks, school supplies, enrollment fees, contributions to the Parents' Association (APAF), photocopies, extraordinary fees, tuition payments, private transportation, among others. The data are converted into monthly values to facilitate better analysis and interpretation, and the total amount is divided by the number of household members in order to prevent households with several school-age children from reporting a relatively higher level of spending (Cuenca & Urrutia, 2019).

Public policies, such as the Early Childhood Education Programs implemented by the Ministry of Education of Peru, directly influence educational coverage (MINEDU, 2023). Policies involving subsidies or incentives for families, as well as the expansion of educational infrastructure, are key strategies for improving coverage in regions such as Puno.

The actions implemented by regional governments to ensure access to and continuity of education for children aged 3 to 5 years have been varied. These include communication strategies aimed at families to raise awareness about the importance of the right to education and early childhood education; the development of specific local plans to guarantee enrollment, retention, and reintegration; as well as monitoring of students' educational progress (Defensoría del Pueblo, 2022).

In the case of early childhood education in the Ancash Region, coverage is below 50%. In 2022 it reached only 49.0% of the population, meaning that more than half of children between 0 and 5 years of age receive no type of formal education from either the public or private sector (Olga & Aguirre, 2022).

Article 201.1 of the Regulations of the Teacher Reform Law, approved through Supreme Decree No. 004-2013-ED, establishes that the rationalization of teaching positions is a permanent, mandatory, and priority process aimed at identifying staff

surpluses and needs in public educational institutions in order to balance educational supply and demand. This process is carried out with flexible criteria, taking into account geographic, socioeconomic, and demographic realities, as well as pedagogical conditions and limitations in infrastructure and human resources. Furthermore, Article 201.2 establishes that this rationalization process is conducted annually in accordance with the regulations issued by the Ministry of Education (MINEDU, 2024).

METHODS

For the application of the statistical test in this research, multiple linear regression will be used, since this model is the most appropriate for analyzing the impact of several independent variables on a continuous dependent variable (in this case, coverage of goals). It allows the study of the simultaneous relationships between educational demand, its determinants, and the coverage of educational targets.

In this research, the specific objectives were first tested, which allowed the consolidation of the general objective of the study. The design applied in this work is a non-experimental longitudinal design. According to Hernández (2014), longitudinal designs are studies that collect data at different points in time in order to make inferences about the evolution of a problem or phenomenon, as well as its causes and effects. Panel data referring to the study variables were collected for the period 2022–2024.

Model specification:

$$\text{Coverage Targets} = \beta_0 + \beta_1 \text{ Educational Demand} + \beta_2 \text{ Geographic Location} + \beta_3 \text{ Educational Infrastructure} + \varepsilon$$

Where:

- β_0 : Model intercept (constant)
- $\beta_1, \beta_2, \beta_3$: Coefficients that show the magnitude of the relationship between the independent variables and the coverage of targets
- ε : Error term or disturbance term that captures the variations not explained by the model

RESULTS

The availability of educational facilities, which are part of the educational supply, during the period 2022–2024 shows a moderate variation in the total number of cases recorded in the districts of the province of Puno. In 2022, there were 187 educational facilities, a figure that increased to 207 in 2023, representing an approximate growth of 10.7%. By 2024, a slight reduction to 206 facilities is observed; however, this variation is not significant, indicating a tendency toward stabilization in the availability of educational facilities during the years analyzed.

The district of Puno concentrates the largest number of facilities during the three years analyzed (51 in 2022; 58 in 2023 and 2024). This pattern can be explained by its status as the provincial capital, its higher population density, and the concentration of institutional services, which increases both the occurrence and the registration of cases. Likewise, the predominance of the urban area within this district stands out, representing approximately 86% of the total in 2023 and 2024, suggesting a dynamic associated with urbanization processes and greater statistical visibility.

The district of Acora ranks second in terms of availability of educational facilities (35 in 2022; 41 in 2023 and 2024), with a marked rural predominance (around 95% of the district total). This characteristic may be linked to structural conditions typical of rural contexts, such as limitations in access to basic services, lower preventive coverage, or higher levels of socioeconomic vulnerability.

Other districts such as Capachica, Coata, and Chucuito show slight increases between 2022 and 2023, and then maintain constant values in 2024. In contrast, districts such as Mañazo, Atuncolla, Huata, Pichacani, San Antonio, and Tiquillaca show sustained stability throughout the three years, which could indicate that the phenomenon maintains a constant structural behavior in these territories.

From the urban–rural perspective, although the largest absolute volume is concentrated in the urban area of the district of Puno, most districts show a predominance of rural areas. This suggests that the phenomenon is not exclusively urban but rather presents a differentiated territorial distribution, with particular dynamics depending on geographic and demographic contexts.

Overall, the results indicate that the increase observed between 2022 and 2023 does not constitute a sustained upward trend but rather a specific variation followed by stabilization. The persistence of similar figures in 2023 and 2024 indicates that the phenomenon maintains a constant magnitude in the province, requiring targeted interventions in districts with the highest concentration of cases, especially Puno and Acora, as well as differentiated strategies according to urban and rural contexts.

The following table details the evolution and distribution of early childhood education facilities.

Table 1.

Early Childhood Education Facilities in the Province of Puno

District	2022 Urban	2022 Rural	2022 Total	2023 Urban	2023 Rural	2023 Total	2024 Urban	2024 Rural	2024 Total
Puno	45	6	51	50	8	58	50	8	58
Acora	2	33	35	2	39	41	2	39	41
Amantani	0	6	6	0	7	7	0	7	7
Atuncolla	0	9	9	0	9	9	0	9	9
Capachica	0	14	14	0	15	15	0	15	15
Chucuito	0	9	9	0	11	11	0	11	11
Coata	0	15	15	0	15	15	0	15	15
Huata	0	5	5	0	5	5	0	5	5
Mañazo	4	3	7	4	3	7	4	3	7
Paucarcolla	0	8	8	0	8	8	0	8	8
Pichacani	2	6	8	2	6	8	2	6	8
Platería	0	8	8	0	9	9	0	8	8
San Antonio	0	3	3	0	3	3	0	3	3
Tiquillaca	0	3	3	0	3	3	0	3	3
Vilque	0	6	6	0	8	8	0	8	8
Total			187			207			206

Source: ESCALE (2022–2024).

Allocation of Teachers in Early Childhood Education (2022–2024)

Regarding the allocation of teachers in early childhood education during the period 2022–2024, the data show a relatively stable pattern with a slight upward trend in the total number recorded in the province. In 2022, 460 teachers were reported; this figure increased to 462 in 2023 and 468 in 2024. Although the absolute increase is moderate (8 cases over three years, equivalent to 1.7%), the trend indicates that the phenomenon does not show a reduction but rather a sustained persistence over time.

This behavior suggests the presence of structural factors that maintain the incidence of the phenomenon, such as socioeconomic conditions, demographic characteristics, or territorial dynamics specific to the province. Likewise, the slight increase could be associated with improvements in recording and reporting systems, rather than with an abrupt rise in actual occurrence.

From a territorial perspective, the district of Puno consistently concentrates more than 55% of the provincial total during the three years evaluated (256 in 2022; 257 in 2023; 262 in 2024). This predominance highlights a strong centralization of the phenomenon in the provincial capital. The internal distribution shows a marked predominance of the urban area (approximately 95% of the district total), which can be explained by higher population density, concentration of services and institutions, as well as more effective detection and reporting mechanisms. In this sense, urbanization emerges as a determining factor in the observed magnitude.

Secondly, the district of Acora presents the highest number of cases among predominantly rural districts (48 in 2022; 47 in 2023 and 2024). Unlike Puno, most cases in this district are concentrated in rural areas (more than 80%), demonstrating that the phenomenon is not exclusively urban. This situation may be related to limitations in access to basic services, population dispersion, and structural vulnerability typical of rural contexts.

On the other hand, districts such as Coata and Mañazo show a progressive increase during the analyzed period, particularly Mañazo (from 12 in 2022 to 16 in 2024), which may indicate a gradual expansion of the phenomenon toward less urbanized areas or improvements in local reporting capacity. In contrast, districts such as Capachica, Pichacani, and Platería present slight downward variations, although these do not represent a sustained decreasing trend.

Similarly, several districts maintain a constant stability throughout the three years, including Amantaní, Atuncolla, Huata, San Antonio, and Tiquillaca. This stability may indicate the presence of a constant structural behavior of the phenomenon, associated with relatively stable demographic and social characteristics.

From an urban–rural perspective, a dual dynamic can be observed: quantitatively, the largest volume is concentrated in the urban area of the district of Puno, while territorially, most districts show a rural predominance. This finding demonstrates that the phenomenon has a differentiated distribution according to geographic context, implying the need for differentiated intervention strategies: targeted actions in urban areas with high population concentration and community-based strategies in rural areas with dispersed populations, see table 2.

Table 2

Teachers in Early Childhood Education in the Province of Puno

District	2022 Urban	2022 Rural	2022 Total	2023 Urban	2023 Rural	2023 Total	2024 Urban	2024 Rural	2024 Total
Puno	244	12	256	245	12	257	249	13	262
Acora	7	41	48	8	39	47	8	39	47
Amantani	0	9	9	0	9	9	0	9	9
Atuncolla	0	13	13	0	13	13	0	13	13
Capachica	0	20	20	0	19	19	0	17	17
Chucuito	0	15	15	0	16	16	0	15	15
Coata	0	24	24	0	24	24	0	26	26
Huata	0	8	8	0	8	8	0	8	8
Mañazo	8	4	12	9	5	14	11	5	16
Paucarcolla	0	13	13	0	14	14	0	14	14
Pichacani	5	7	12	5	7	12	5	6	11
Plateria	0	14	14	0	13	13	0	13	13
San Antonio	0	3	3	0	3	3	0	3	3
Tiquillaca	0	3	3	0	3	3	0	3	3
Vilque	0	10	10	0	10	10	0	11	11
Total			460			462			468

Source: ESCALE (2022–2024)

Synthesis of Results

In summary, the results show that the phenomenon maintains a constant magnitude with a slight increasing trend, mainly concentrated in the district of Puno, and presenting differentiated characteristics between urban and rural areas. The absence of a significant reduction during the analyzed period indicates the need to strengthen public policies and preventive strategies with a territorial and contextualized approach.

CONCLUSIONS

The analysis of the data corresponding to the 2022–2024 period shows that the phenomenon under study presents a stable behavior with a slight increasing trend,

without significant reductions during the evaluated years. This situation confirms its persistent and structural character in the province.

A high concentration of cases was identified in the district of Puno, which exceeds 50% of the provincial total in the second table analyzed. This centralization demonstrates that urban dynamics strongly influence the general behavior of the phenomenon.

The predominance of the urban area in the district of Puno contrasts with the mostly rural dynamics observed in the other districts, revealing a differentiated territorial distribution that requires specific intervention approaches according to geographic context. The district of Acora stands out as the second territory with the highest incidence, highlighting its predominantly rural character. This finding demonstrates that the phenomenon is not exclusive to urban areas, and that rural zones present sustained conditions of vulnerability.

Districts such as Coata and Mañazo show progressive increases during the evaluated period, which could indicate a gradual expansion of the phenomenon toward areas with lower population density or improvements in local reporting systems. In districts such as Amantaní, Atuncolla, Huata, San Antonio, and Tiquillaca, stability is observed throughout the three years analyzed, suggesting a constant pattern associated with relatively stable demographic and social characteristics.

The moderate growth observed between 2022 and 2024, especially in the second table, indicates that the problem does not show a decreasing trend, and therefore its continuation is projected in the short term if targeted and sustained interventions are not implemented.

Overall, the results confirm the need to strengthen public policies with a differentiated territorial approach, prioritizing the district of Puno due to its high concentration of cases and designing specific strategies for rural contexts such as Acora and other predominantly rural districts.

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RELATIONSHIP BETWEEN MANAGERIAL LEADERSHIP STYLES AND ORGANIZATIONAL CLIMATE IN EARLY CHILDHOOD EDUCATION INSTITUTIONS IN THE DISTRICT OF SICUANI

Fernández Machaca, Roxana María

ABSTRACT

This study aimed to determine the relationship between leadership styles and organizational climate in early childhood education institutions. This basic correlational research employed a non-experimental, cross-sectional design. The study population consisted of 106 early childhood teachers from the city of Sicuani, who completed two structured Likert-scale questionnaires, one for each variable. Both instruments were validated by expert judgment and demonstrated high levels of reliability. The results showed a positive and statistically significant relationship between leadership styles and organizational climate ($r = 0.751$, $p < 0.001$), with democratic leadership exhibiting the strongest correlation ($r = 0.792$). These results demonstrate that leadership styles, specifically democratic leadership, directly influence the teachers' work environment. It is concluded that democratic leadership fosters the development of participatory and collaborative organizational climates, while other leadership styles have less impact on the educational organization. Consequently, it is recommended to strengthen leadership training with participatory leadership, thereby fostering inclusive and humanized educational management. Therefore, it is recommended to strengthen leadership training in participatory and communicative leadership, guiding the development of effective and humanized educational management.

Keywords: autocratic leadership, democratic leadership, laissez-faire leadership, organizational climate.

INTRODUCTION

Managerial leadership and organizational climate are two fundamental and important components that directly influence the success and efficiency of educational institutions (Peché et al., 2023).

Campos (2012) indicates that the essence of leadership is built when the relationships within the team are recognized and strengthened, taking into account that the relationship they have as a team is based on mutual trust, respect for ideas, and sincere appreciation of the contributions and suggestions of each team member; leadership is key to facing and solving problems, considering that each member takes on challenges in a shared manner.

Globally, in recent years educational institutions have faced significant challenges related to school management, in which the role of the principal has become increasingly important, not only as a pedagogical administrator but also as an academic leader capable of influencing the organizational climate that promotes teacher performance, motivation, participation of teachers and the entire educational community. According to Northouse (2022), Leadership is a process of social influence that guides people towards their common goals, adapting to the needs of the environment and thus promoting professional development, which is essential in educational contexts such as in the district of Sicuani.

In the Sicuani district, early childhood education institutions face challenges related to cultural diversity, limitations, and a high demand for educational equity. This research, conducted in the Sicuani district in 2024, seeks to find a solution to this problem and explore how leadership styles impact the organizational climate, directly affecting teachers' working conditions and, consequently, the quality of early childhood education.

Evidence gathered at the local level shows how limited training in educational management has fostered the presence of directive and laissez-faire leadership styles, which restrict the development of participatory and motivating practices in educational institutions. According to reports from the Regional Directorate of Education (DRE) in the Sicuani district, a significant number of administrators struggle to promote positive work environments. This situation is reflected in teachers' professional performance and the quality of teaching and learning at the early childhood education level.

Given this reality, it is necessary to analyze the relationship between managerial leadership styles and organizational climate, since the latter directly influences teacher well-being and teaching and learning processes.

The insufficient empirical evidence in the urban context of Sicuani justifies developing the present study, which seeks to provide relevant information to strengthen school management and promote a more participatory and quality early childhood education.

Castillo (2018) It indicates that leadership is conceptualized as a dynamic process with social influence through which individuals mobilize and guide a group, leading to the achievement of shared goals and fostering collective commitment and participation. In the educational field, leadership is not limited to directing or ordering administrative documents; it goes beyond that. A leader has the role of guide and communicator, and in turn, promotes the educational institution in a way that favors the educational and cognitive development of each teacher, which in turn benefits the entire educational community in terms of workplace harmony. According to Yukl (2013), This process focuses on how a person exerts their impact on others to achieve organizational goals, highlighting the role of leader and facilitating the harmonization of individual efforts towards a unified objective.

In broader terms, leadership represents a mechanism of social influence that empowers an individual to guide others in the pursuit of shared goals, thus integrating elements of motivation, strategy, and contextual adaptation. In the educational context, this concept is important because it goes beyond simply managing material resources; it is a process through which leaders can motivate innovative practices in the workplace. Amanchukwu et al. (2015) They indicate that leadership styles constitute tactics or strategies used by managers and that these must be adapted according to the context, situations, and work groups, since these tools help to lead effectively in the work environment. Likewise, according to the authors, there are different leadership styles.

The autocratic leadership style is characterized by a management style where the central figure is the absolute leader, assuming their role unilaterally and making decisions independently without involving their colleagues. This approach is based on constant control and authority centered on the leader, where the team focuses exclusively on completing tasks without contributing ideas. Compliance and orders are prioritized to ensure efficiency (De Hoogh & Den Hartog, 2020).

Democratic leadership prioritizes the active participation of the entire community or team members in decision-making, fostering a collaborative and positive environment where the leader values the contributions of each individual, encouraging open dialogue and seeking consensus before implementing key actions. Also known as participative leadership, it stands in opposition to the autocratic style. It involves consulting with subordinates on the planning and development of all activities in order to promote widespread participation (Campos et al. 2020).

On the other hand, Laissez-faire leadership, characterized by the leader's active "non-intervention," allows team members to make autonomous decisions and

manage their activities without constant management supervision or frequent feedback.

Organizational climate is manifested through the beliefs and values that members of the organization attribute to their work environment, encompassing key elements such as the quality of internal communication, recognition of achievements, the perception of fairness in treatment, and the level of support provided by the hierarchy—all of which shape daily dynamics and collective productivity.

Carrillo and Bolívar (2023) Organizational climate reflects the diverse values, attitudes, and beliefs of an organization's employees, which contribute to its reason for being. These elements become part of the work environment and define an organization's identity, projecting an image not only internally but also externally.

Various studies show that the leadership style chosen by each director influences the motivation, job satisfaction, and commitment to the institution of the educational community. De la Cruz (2022), His research shows that leadership styles directly influence several aspects, the most important being motivation, factors that indirectly affect academic and work performance and the quality of educational service.

Cutipa (2020) The study aimed to establish the relationship between leadership style and organizational climate in the educational institutions of the Pallpata district network, in the province of Espinar, Cusco. The design was non-experimental and correlational-transactional. The results showed a positive and significant relationship between both variables, indicating that effective leadership contributes significantly to a better organizational climate in the educational institutions studied.

Surco (2024) This study examined the relationship between leadership styles and organizational climate at the Regional Council of the Regional Government of Arequipa, with a population of 55 employees and a quantitative approach. The results showed significant correlations between transformational and transactional leadership styles and organizational climate, demonstrating a moderate positive association. This finding underscores the importance of these styles in the public sector for promoting commitment and efficiency, especially in Andean regions like Arequipa, where transformational leadership can mitigate administrative challenges similar to those found in Sicuani.

Cárdenas (2018) This study focused on organizational commitment and job satisfaction at the Regular Basic Education Institution, La Salle, in Urubamba. It employed a quantitative approach with a non-experimental, descriptive-

correlational, and cross-sectional design. The research included the entire teaching staff of 30 individuals, utilizing validated surveys and questionnaires. The results indicated a strong positive correlation between organizational commitment and job satisfaction, with a Spearman's rho correlation coefficient of 0.801, suggesting that greater job satisfaction is associated with greater organizational commitment.

Chura (2019) This study investigated the relationship between leadership and organizational culture at the IESTP El Descanso-Túpac Amaru Branch, in the province of Canas, Cusco. It employed a non-experimental, descriptive-correlational design with a sample of 4 faculty members and 26 students. Validated questionnaires revealed that 60% of respondents perceived the presence of pseudo-leaders, and 20% identified transactional leaders, while perceptions of transformational and absent leaders were lower. In terms of organizational culture, 70% of participants rated it as good, suggesting a suitable institutional environment, although with areas for improvement.

It is important to analyze and study the current situation of early childhood education institutions in the Sicuani district, given the difficulties related to organizational climate experienced in recent years. This reality highlights the need to implement strategies that improve the work environment, effective communication, and greater collaboration. To this end, it is suggested that an existing relationship between leadership styles and organizational climate be explored. In this context, it is necessary to examine whether leadership studies have any relationship with organizational climate, which will allow for a better understanding of its impact on job performance. This research article aims to raise awareness among administrators and the entire educational community about the importance of strengthening leadership styles, considering that these improve the organizational climate, fostering an environment where motivation, active participation, and enthusiasm are present in every activity. Therefore, the objective is to determine the relationship between leadership styles and organizational climate in public early childhood education institutions in the Sicuani district.

METHODS

The research was conducted using a quantitative, basic, and correlational approach, with a non-experimental, cross-sectional design. This was because the variables were not manipulated; the purpose was to analyze the relationship between managerial leadership styles and organizational climate without manipulating the study variables. The design was non-experimental and cross-sectional. According to Hernández (2014), The research method represents "the quantitative, qualitative and mixed routes" to approach the research process, emphasizing the selection of approaches based on the nature of the problem, where

the quantitative prioritizes measurement and statistical analysis, the qualitative the deep understanding of meanings, and the mixed the integration of both for a more complete vision.

As presented by Arias y Covinos (2021) It is conceptualized as “an endless or finite collection of subjects who share common or similar traits.” This is called the unit of study, which for this research consisted of 106 teachers from urban early childhood education institutions in the district of Sicuani. Therefore, a census sampling method was used. Two structured Likert-scale questionnaires were used to collect information. One measured leadership style, considering their autocratic, democratic, and laissez-faire dimensions, and the other measured organizational climate. Both instruments were validated through three expert reviews and subjected to reliability testing, obtaining Cronbach's alpha coefficients greater than 0.80, which demonstrates adequate internal consistency for the application of these questionnaires.

Data processing and analysis were performed using the SPSS statistical software, version 25. Descriptive statistics were used for the analysis of frequencies and percentages, and inferential statistics were used using Spearman's rank correlation coefficient, considering a statistical significance level of 0.05.

RESULTS

This section presents the results obtained from the analysis of the data collected in this research, which are shown below: Regarding the relationship between leadership styles and organizational climate in early childhood education institutions in the district of Sicuani, the results show that the medium leadership level is the highest frequent with 51 teachers (48.1%), followed by the high level with 39 teachers (36.8%), while the low level reaches 16 teachers with 15.1%. Likewise, in relation to organizational climate, it is evident that the medium level is predominant with 47 teachers representing 44.3%, the high level with 42 teachers and a percentage of 39.6%, and finally the low level with 17 teachers with 16.1%. These results demonstrate that most educational institutions present organizational conditions and leadership practices at an average level, which suggests the need to strengthen management strategies to improve the work environment, as shown in Table 1.

Table 1

Relationship between leadership styles and organizational climate

Leadership styles	Organizational climate			Total
	Hight	Medium	Low	
High	29 (27.4 %)	8 (7.5 %)	2 (1.9 %)	39 (36.8 %)
Medium	10 (9.4 %)	33 (31.1 %)	8 (7.5 %)	51 (48.1 %)
Low	3 (2.8 %)	6 (5.7 %)	7 (6.6 %)	16 (15.1 %)
Total	42 (39.6 %)	47 (44.3 %)	17 (16.1 %)	106 (100 %)

Note. The table shows the frequencies and percentages of the relationship between leadership style levels and organizational climate levels according to the perception of 106 teachers surveyed in Sicuani 2024.

Regarding autocratic leadership and organizational climate, the results show that the medium level of autocratic leadership is the most frequent, with 48 teachers (45.2%), followed by the high level with 38 teachers (35.8%), while the low level is present in 20 teachers (18.9%). Similarly, with respect to organizational climate, the medium level predominates, with 47 teachers (44.3%), followed by the high level with 38 teachers (35.8%), and the low level with 21 teachers (19.9%). These results demonstrate that autocratic leadership is primarily found at intermediate levels and is associated with a medium organizational climate, suggesting that this leadership style influences the perception of the work environment in educational institutions in the Sicuani district, as shown in Table 2.

Table 2

Relationship between autocratic leadership and organizational climate

Autocratic leadership	Organizational climate			Total
	High	Medium	Low	
High	26 (24.5 %)	10 (9.4 %)	2 (1.9 %)	38 (35.8 %)
Medium	9 (8.5 %)	31 (29.2 %)	8 (7.5 %)	48 (45.2 %)
Low	3 (2.8 %)	6 (5.7 %)	11 (10.4 %)	20 (18.9 %)
Total	38 (35.8 %)	47 (44.3 %)	21 (19.9 %)	106 (100 %)

Note: The table presents the frequencies and percentages of the relationship between levels of autocratic leadership and the organizational climate dimension, according to the perception of the 106 teachers surveyed in the Sicuani district, 2024.

Regarding the relationship between democratic leadership and organizational climate, the results show that the high level is present in 39 teachers (39.6%), followed by the medium level with 47 teachers (44.3%), while the low level is represented by 20 teachers (18.9%). As for organizational climate, a similar distribution is observed between the high and medium levels, both with 42 teachers (39.6%), and a lower percentage at the low level with 22 teachers (20.8%). These results indicate that the democratic leadership style is predominantly found at medium and high levels, and is associated with a favorable organizational climate for the entire team, suggesting its positive contribution to strengthening the work environment in educational institutions, as shown in Table 3.

Table 3

Relationship between democratic leadership and organizational climate

Democratic Leadership	Organizational climate			Total Medium
	High	Medium	High	
High	30 (28.3 %)	7 (6.6 %)	2 (1.9 %)	39 (36.8 %)
Medium	10 (9.4 %)	30 (28.3 %)	7 (6.6 %)	47 (44.3 %)
Low	2 (1.9 %)	5 (4.7 %)	13 (12.3 %)	20 (18.9 %)
Total	42 (39.6 %)	42 (39.6 %)	22 (20.8 %)	106 (100 %)

Note. The table presents the frequencies and percentages of the relationship between the levels of democratic leadership and the organizational climate dimension, according to the perception of the 106 teachers surveyed in the Sicuani district, 2024

Regarding the relationship between laissez-faire leadership and organizational climate, the results show that the medium level of laissez-faire leadership is the most frequent, with 47 teachers (44.3%), followed by the high level with 36 teachers (34%), and the low level with 23 teachers (21.7%). Similarly, with respect to organizational climate, the medium level predominates with 47 teachers (44.3%), while the low level is found in 26 teachers (24.6%) and the high level in 33 teachers (31.1%). These results demonstrate that laissez-faire leadership is primarily associated with medium and low levels of organizational climate, suggesting that a lack of supervision and guidance can negatively affect the work environment in the evaluated educational institutions, as shown in Table 4.

Table 4

Relationship between laissez-faire leadership and organizational climate

Laissez-faire leadership	Organizational climate			Total
	High	Medium	Low	
High	23 (21.7 %)	10 (9.4 %)	3 (2.8 %)	36 (34.0 %)
Medium	8 (7.5 %)	30 (28.3 %)	9 (8.5 %)	47 (44.3 %)
Low	2 (1.9 %)	7 (6.6 %)	14 (13.2 %)	23 (21.7 %)
Total	33 (31.1 %)	47 (44.3 %)	26 (24.6 %)	106 (100 %)

Note. Frequencies and percentages derived from surveys applied to 106 teachers in 2024.

CONCLUSIONS

Based on the research findings, it is concluded that there is a positive and statistically significant relationship between leadership styles and organizational climate in early childhood education institutions in the Sicuani district in 2024. However, these institutions exhibit varying levels of development in terms of leadership practices and organizational climate.

Regarding autocratic leadership, a moderate positive correlation was found with organizational climate. While this style can be useful for maintaining organizational structure and compliance with rules, its predominance limits communication, creativity, and motivation among teaching staff. Consequently, it is recommended that principals adopt autocratic leadership only in specific situations that require control or institutional discipline.

Regarding democratic leadership, the highest correlation with organizational climate was observed, demonstrating that this style is the most effective for promoting positive work environments. Institutions where principals encourage participation, dialogue, and shared decision-making exhibit climates characterized by trust, cooperation, and motivation.

Finally, with respect to laissez-faire leadership, the results revealed a low positive correlation, indicating a weak relationship with organizational climate. Although some teachers may perceive a degree of autonomy under this style, the lack of direction and follow-up generates uncertainty, disorganization, and weakens group cohesion. In the educational context of Sicuani, where pedagogical guidance and support are essential, this leadership style is not suitable for ensuring a stable and committed work environment.

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PUBLIC SECTOR ACCOUNTING POLICIES IN THE PRESENTATION OF FINANCIAL STATEMENTS IN REGIONAL GOVERNMENTS OF PERÚ

Huaman Yucra, Saul

ABSTRACT

Accounting policies for the presentation of public sector financial statements are the principles and standards used for presenting the financial information of government entities. These policies encompass important decisions regarding the basis for preparing financial statements. It is crucial that accounting policies in the public sector are consistent, transparent, and comply with the specific accounting standards for government entities. The objective is to analyze the strategies for implementing accounting policies in public sector financial statements, which is essential to ensuring transparency in the preparation of financial statements. This process follows specific accounting standards for the public sector and requires the application of appropriate accounting policies to accurately reflect the financial reality of public entities. The preparation of financial statements in these entities includes the balance sheet, the income statement, and the statement of cash flows. It is fundamental that public sector financial statements are transparent, reliable, and in accordance with applicable accounting standards to ensure the proper management of public resources. The presentation of financial statements in the public sector is a fundamental process for communicating the financial situation, thus ensuring that government entities accurately reflect their financial position. and reliable through the General Account of the Republic, which contains quality, useful, timely information, with international standards, so that they can understand and adequately evaluate the financial management of public resources for decision-making.

Keywords: financial statements; public sector; public policies; accounting standards.

INTRODUCTION

The regulatory complexity at a global level, the diversity of accounting regulations, and the evolution of international standards can hinder the adoption of

uniform accounting practices in the public sector according to Chérrez et al., (2020) The adoption of international accounting standards in the public sector is to ensure that the information is transparent, timely, and comparable, which will be a substantial input for decision-making, Ugalde (2022) the application of the International Public Sector Accounting Standards (IPSAS) in public entities becomes a conditioning tool for internal and external control and auditing.

Thus, the complexity and challenge of adapting these standards to the specific needs of government entities is due to the lack of training for the personnel in charge of accounting in the public sector, who face difficulties in correctly understanding and applying them. IPSAS, for Galarza & Raza (2023), they indicate that the lack of internal policies is not very clear on the part of the governing body of public finances when it comes to carrying out the preparation and presentation of financial statements. On the other hand, the limited training of financial personnel in the entities on the application of the IPSAS.

The misinterpretation of the IPSAS can lead to the improper application of accounting standards, resulting in errors in the presentation of financial statements and non-compliance with regulations. Likewise, the regulatory complexity in the application of the IPSAS can be complex and detailed, which makes their implementation difficult in public sector entities with organizational structures and accounting processes that are often different from those of the private sector, according to Pozo et al., (2022) The incorrect application of the General Accounting Standards - IAS can result in erroneous outcomes in the financial statements.

Holguín & Barcia (2023) The implementation of the IPSAS as an important resource to improve the presentation of an organization's financial statements should be considered as a regulation for the presentation of accounting information, Munevar (2023) In the Colombian context, historically it has had a relationship with international institutions such as the International Monetary Fund (IMF), the implementation of accounting standards in compliance with accounting regulations, which will ensure high-quality compliance with standards and harmonization with international organizations, in the same context, Gormaz & Montecino (2025) The implementation of IPSAS in the Republic of Chile aims to improve transparency and the quality of financial information. On the other hand, Arévalo & Montero (2024) state that accounting practices with the International Public Sector Accounting Standards (IPSAS) have an impact on transparency in the accountability of public institutions in Ecuador.

THEMATIC DEVELOPMENT

International Public Sector Accounting Standards - IFAC

Arévalo and Montero (2024) In 1977, the International Federation of Accountants (IFAC) was founded, with the aim of allowing the accounting profession to excel in the presentation of financial statements, Ablan (2013) International accounting standards are oriented towards an accounting model proposed by the International Federation of Accountants - IPSAS. In recent years, they have been crucial regarding changes in all areas where the operation of a public organization occurs. On a global scale, the application of IAS involves governments making decisions with a vision of public management, which will play a strategic role in accounting systems as a key element of modern management.

Freire & Montero (2024) The implementation of IPSAS in government entities allows for improved transparency of financial information, on the other hand, Pantoja (2024) The implementation of International Public Sector Accounting Standards has had a significant impact on fiscal audits in the analysis of financial information., (Uzhca & Montero (2024) The IPSAS constitute a set of accounting policies with an international scope, and their adoption by entities aims primarily at the transparency of financial statements.

Choquehuayta et al., (2021) They state that the ways of applying accounting policies in the preparation and presentation of the legal and technical situation of the entity's assets, liabilities, and equity, the descriptive-analytical method was applied, through the analysis of financial statements and description via a survey of the staff's knowledge of accounting policies, it is noted that the impact of the application of International Public Sector Accounting Standards (IPSAS), Uzhca & Montero (2024) In an international context, it has been evident that there have been changes in public sector entities, which is affecting many governments by focusing on accounting systems to ensure the quality and transparency of information in compliance with government accounting standards with the adaptation of the IPSAS.

Benitez et al., (2025) The adoption of IPSAS improves the quality of financial statements by complying with clear and comparable criteria, which strengthens control and transparency in public administration, Galván et al., (2019) They claim that the preparation of financial statements is an accounting task, carried out according to the standards based on what is stipulated in the IPSAS. It should be taken into account that public policies allow for obtaining benefits from the application of the new regulations. In recent years, government sector entities have been integrating information according to the new standard regarding accounting practices in the public sector. Thus, public officials or agents involved in the

presentation of financial statements actively participate in its application and adoption as an accounting policy under the IPSAS.

Calvache (2025) the IPSAS The main function is the transparency of governments' accounting information, in which the standardization of financial information allows them to face the various challenges and difficulties in the closing of each fiscal period. Illescas-Guillén et al., (2020) The IPSAS, as a policy, allows users to systematize the application of NIC-SP for the presentation of accounting information. Thus, entities, as part of a project related to the modernization of tools to integrate public finance actions, which is endorsed by the Ministry of Economy and Finance in Peru, the General Directorate of Public Accounting, as responsible for the processes of reviewing and supervising the presentation of financial statements, according to the regulatory standards in the Peruvian state, has decided to adopt an indirect application regarding the presentation and preparation of financial statements.

Ruiz & Montero (2025) The adoption of IPSAS contributes to the effectiveness of financial management in government entities, as it will help improve the quality of information in financial reports, Saeteros-Molina et al., (2020) Government Accounting is a set of procedures aimed at combining asset operations with budgetary operations. Additionally, it involves the obligations for the application of the IPSAS by the entities that make up the public sector in the Budgetary Classifier, which contains the details of expenses and income.

Financial statements

Becerra et al., (2023) The analysis of financial statements as a tool allows for relative comparisons, which facilitates decision-making and leads to the conclusion that financial strategic planning processes determine strategies and objectives, including a forward-looking analysis for decision-making, and in this way the economy is quantified with the help of financial statements.

Estrada (2024) It mentions that financial statements contribute to the recognition of financial information, which is essential for determining the current situation of a public or private and legal entity. In conclusion, regarding financial analysis as an evaluation tool for decision-making, it significantly improves what is reflected in the financial statements.

Muñoz (2024) It states that in the public sector, the preparation of financial statements is carried out through the use of software applications such as the Integrated Financial Administration System, which constitutes a mechanism of automated procedures in which information is recorded and processed. The purpose is to generate useful and reliable information through financial statement reports,

which allows for decision-making. It is concluded that the recording of income and expenses through the SIAF significantly influences the financial statements.

CONCLUSIONS

The use of the IPSAS transforms public accounting by ensuring relevant, reliable, and comparable information, contributing to a more efficient and responsible management of state resources. Its application continues to promote improvements in financial practices, aligning the public sector with international standards for greater social welfare.

The adoption of IPSAS in recent years is part of an ongoing process of accounting reform aimed at strengthening transparency in the preparation and presentation of financial statements. The implementation process has driven the modernization of administrative and accounting systems, as well as improvements in inventory processes, asset control, and public asset management. Despite the progress, operational and structural challenges persist, such as the adaptation of IT systems, the quality of base information, resistance to organizational change, and the availability of financial and human resources.

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EVALUATION OF THE REGULATORY FRAMEWORK FOR DEBT-FUNDED PROJECTS AND FIDIC CONTRACTS, 2025, 2025

Ito Mamani, Aduard Sergio

ABSTRACT

This review article aims to evaluate the regulatory framework applicable to debt-funded projects employing FIDIC contracts, both internationally and within the Peruvian context, during the 2021–2025 period. The study population comprises international regulatory frameworks and contractual models, utilizing a census sample. The results demonstrate that FIDIC contracts contribute to improved risk allocation, dispute reduction, and greater efficiency in project execution compared to traditional Peruvian public procurement schemes. It is concluded that their implementation requires regulatory adjustments, institutional strengthening, and capacity building for public sector operators.

Keywords: FIDIC contracts, public debt, international procurement, project management, regulatory framework.

INTRODUCTION

Globally, the construction industry faces a paradigm of high conflict. According to the International Chamber of Commerce (2021), approximately one-quarter of international arbitrations stem from this sector, generating cost overruns that, in developed economies such as Australia, exceed 5 billion dollars annually in efficiency losses (CRC, 2009). This issue has driven the transition from traditional contracts toward standardized collaborative models, where **FIDIC contracts** have emerged as the "gold standard" for large-scale projects funded by multilateral organizations such as the World Bank (Figuerola, 2020).

In the Peruvian case, the reality presents a critical gap. While international regulations seek dispute prevention, the national legal framework—primarily governed by the **State Procurement Law (LCE)**—has shown structural flaws in contractual management (Flores, 2019). This is evidenced by the alarming figure of stalled public works, whose economic losses exceed 29 billion soles (Contraloría, 2022), due to deficient technical files, prolonged arbitrations, and an asymmetrical risk distribution that stifles the contractor and leaves the State unprotected.

Faced with this scenario, recent experiences such as **Government-to-Government (G2G)** contracts and **Special Public Investment Projects (PEIP)** have introduced tools like Project Management Offices (PMO) and BIM methodology (Fraguela, 2021). However, the integration of FIDIC contracts in debt-funded projects should not be viewed as an isolated "magic formula." As Medina (2023) argues, the effectiveness of a standard contract resides not only in its clauses but in the internalisation of its philosophy by public operators.

The objective of this article is to evaluate the viability of the current Peruvian regulatory framework to support the execution of FIDIC contracts in debt-funded projects. It is justified socially, by seeking to reduce the infrastructure deficit; practically, by offering guidelines for decision-makers; and theoretically, by contrasting national administrative law with the best practices of the international *Lex Mercatoria*.

THEMATIC DEVELOPMENT

Divergence between the National Regulatory Framework and International Standards

Infrastructure project management in Peru has traditionally operated under a confrontational scheme. According to Medina (2021), State Procurement regulations lack the necessary flexibility for officials to choose the best procurement strategy based on the nature of the project. While FIDIC contracts are based on mutual trust and proactive management, Law No. 30225 focuses on formal compliance and *ex-post* control, leading to systemic paralysis in the face of any technical unforeseen event.

Comparative Analysis of Contractual Efficiency (NEC vs. FIDIC)

Based on the research of Cuizano (2023) and Pinedo (2022), it is observed that specialists' perceptions of standard contracts are not uniform. When contrasting **NEC models** (used in the Pan American Games) and **FIDIC models** (preferred in development loans), distinct levels of maturity are identified among operators:

Table 1

Dimension of Analysis	NEC Model (UK)	FIDIC Model (Switzerland/Global)
Primary Focus	Schedule management and technical collaboration.	Risk management and contract administration.
Perception in Peru	42.5% of specialists consider it deficient due to its administrative complexity (Cuizano, 2023).	40% consider it efficient, due to its long-standing track record in World Bank projects.
Dispute Resolution	"Early Warning" management.	<i>Dispute Adjudication Boards (DAB)</i> <i>with a 98% success rate (Cuentas & Nuviala, 2022).</i>

This comparison suggests that for debt-funded projects, the **FIDIC model** offers a "Books" structure (Red, Yellow, Silver) that is better suited to the complexity of the civil engineering works that the Peruvian State needs to complete.

Legal Incorporation and the Role of Special Projects (PEIP)

The adoption of these contracts in Peru has been fragmented. As Fraguera (2021) points out, the regulations have evolved through "legal patches" (see Table 2 of the original manuscript) born out of urgency, such as Emergency Decree (D.U.) No. 021-2020. However, the current challenge is not merely issuing decrees, but achieving knowledge transfer.

Table 2

Regulatory Instrument	Publication Date	Purpose	Tool
Supreme Decree (D.S.) No. 250-2020-EF	9/03/2020	Incorporation of the Dispute Resolution Board into the dispute settlement clause for active construction contracts.	DAB / DRB (Dispute Adjudication Board).
Supreme Decree (D.S.) No. 289-2019-EF	9/08/2019	Approval of provisions for the progressive incorporation of BIM in public investment.	BIM (Building Information Modeling) usage.
Legislative Decree No. 1444 (Amending Law No. 30225, State Procurement Law)	09/16/2021	Government-to-Government (G2G) contracts or agreements may include clauses for the implementation of a Project Management Office (PMO).	PMO in G2G agreements.
Supreme Decree (D.S.) No. 288-2019-EF	9/08/2020	Approval of guidelines for contracting consultancy services for investment management, investment programs, or investment portfolios.	PMO for the State.
Emergency Decree (D.U.) No. 021-2020	01/23/2020	Incorporation of standardized contracts in Special Public Investment Projects (PEIP).	Standard Form Contracts (NEC, FIDIC, ENAA).
Supreme Decree (D.S.) No. 007-2020-MTC	02/20/2020	Creation of the "Legado" Special Project for the XVIII 2019 Pan American Games.	Legacy and knowledge transfer.

The implementation of a **Project Management Office (PMO)** under FIDIC contracts allows the State not only to receive a physical work but also to learn how to manage risks on an international scale. However, there is a correlation (**$\rho = 0.862$**) indicating that if the conventional contract remains deficient, the international contract will also fail unless the public official's organizational culture is transformed (Cuizano, 2023).

CONCLUSIONS

Philosophical incompatibility, it is concluded that a gap exists between the rigidity of the State Procurement Law (LCE) and the flexibility of FIDIC. The adoption of these contracts in debt-funded projects requires that Peruvian

regulations formally recognize equitable risk allocation as a principle of efficiency, rather than a loss for the State.

Standardization vs. exceptionality, international contracts should not be exclusive to "Special" or G2G projects. Evidence shows that their preventive success (98% in dispute resolution) justifies their general application in high-complexity works to avoid the 29 billion soles in cost overruns identified by the Comptroller General's Office.

Human capital training, the success of FIDIC in Peru does not depend on the document itself, but on the training of engineers and lawyers in contract administration. The creation of a Specialized Technical Corps operating under the standards of the International Federation of Consulting Engineers is recommended.

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ANALYSIS OF THE LEVEL OF TRAFFIC ACCIDENTS ON THE JULIACA – AREQUIPA ROUTE IN THE PERIODS 2022-2024

Lujano Acero, Gianni Fashion

ABSTRACT

The objective of this paper is to analyze the level of traffic accidents recorded on the Juliaca–Arequipa route during the period 2022–2024, identifying trends, causes, and associated structural factors. The research methodology is quantitative, descriptive-comparative, and longitudinal, with a non-experimental design. Secondary data from official reports of the Ministry of Transport and Communications, the National Police of Peru, and SUTRAN (Superintendency of Land Transport of Peru) were used. The results show a significant increase of 31.6% in 2023 compared to 2022, followed by a slight reduction of 11.4% in 2024, without reaching initial levels. Speeding (38%), driver negligence (27%), and invading the opposite lane (18%) are the main causes, accounting for 83% of the accidents. Furthermore, it is identified that informality in passenger transport could act as an indirect structural factor that encourages risky behavior, due to competition for passengers, long working hours, and limited technical oversight. It is concluded that a sustained reduction in accidents requires not only enforcement, but also comprehensive policies for formalization, road safety education, and investment in safe infrastructure.

Keywords: traffic accidents, road safety, informal transport, accident rate, interprovincial transport, longitudinal analysis.

INTRODUCTION

Traffic accidents are one of the leading causes of death worldwide. According to the World Health Organization (2023), approximately 1.19 million people die each year globally as a result of road traffic crashes, while millions more suffer serious injuries and permanent disabilities, making these accidents one of the leading causes of death for people between the ages of 5 and 29. Other studies published in databases such as Redalyc and Peruvian institutional repositories indicate that human error is a determining factor in more than 70% of road traffic accidents. In Peru, the problem is exacerbated on interprovincial highways with complex

geographical conditions, affecting not only human lives but also the economy, impacting the Gross Domestic Product by between 3% and 5% in low- and middle-income countries.

In Latin America, traffic fatality rates remain above the global average, highlighting deficiencies in road infrastructure, enforcement, and road safety culture. In Peru, according to information from the Ministry of Transport and Communications (2022-2024), accidents on national highways represent a considerable percentage of all accidents recorded annually, concentrated mainly on high-traffic interprovincial corridors.

The Juliaca–Arequipa route constitutes a strategic economic corridor in the south of the country, with respect to interprovincial passenger and freight transport. This route crosses a high Andean region with geographical characteristics, including high altitudes exceeding 3,800 meters above sea level, variable climatic conditions (intense rainfall, snowfall, hail, and extreme temperatures), high traffic volume, long distances, and straight sections that encourage speeding, increasing the risk of head-on collisions and rollovers.

Some studies conducted at Peruvian universities and published in databases such as Redalyc indicate that more than 70% of traffic accidents are linked to driver behavior (Gonzales, 2021; Quispe, 2020). However, beyond individual error, it is necessary to analyze the structural factors that encourage such risky behaviors. In this context, the informal passenger transport sector emerges as a relevant element, as it can generate competition for demand, economic pressure on drivers, prolonged working hours, and deficient vehicle maintenance.

Other research indicates that after the pandemic, with the economic reactivation, vehicular traffic in this corridor increased, which may have influenced the variation in accident rates between 2022 and 2024.

Academic research conducted at Peruvian universities highlights that deficient road safety education, informality in transport, and limited enforcement significantly influence accident rates. The supervision of interprovincial transport falls under the purview of SUTRAN (Superintendency of Land Transport of Peru) and the National Police of Peru; however, along extensive corridors, enforcement faces operational limitations. From the perspective of the "Safe System" approach, promoted by the World Health Organization, road safety must be addressed comprehensively, considering infrastructure, regulations, and user behavior.

In this context, this article aims to analyze the level of traffic accidents on the Juliaca-Arequipa route during the years 2022, 2023, and 2024, identifying trends, main causes and variations, and incorporating a discussion on the possible

relationship between informal transport and the persistence of risky driving behaviors. This analysis will contribute to the formulation of prevention strategies and improvements to regional road safety.

METHODOLOGY

The research employs a quantitative approach, a descriptive-comparative level, and a longitudinal, non-experimental design. This design allows for observing the evolution of accident rates without manipulating independent variables, by analyzing official records in their natural context. Official records corresponding to the years 2022–2024 were analyzed.

The population consisted of all officially registered traffic accidents on the Juliaca-Arequipa route during the study period. Sampling was not applied, as the study used a complete database of available records.

The sources of information were official reports from the National Police of Peru, the Ministry of Transport and Communications, and SUTRAN (Superintendency of Land Transport of Peru).

The variables included the total number of accidents, injuries, fatalities, and main causes. Descriptive statistics using frequencies and percentages were employed to identify trends.

For data analysis, descriptive statistics were used, employing absolute and relative frequencies (percentages), which allowed for the identification of trends and interannual variations. The results obtained were organized into comparative tables to facilitate the interpretation of the contextual analysis in order to interpret the observed changes.

RESULTS

The data obtained show a significant variation in the number of accidents recorded during the study period.

Table 1

Number of accidents per year

Year	Accidents	% Change
2022	120	-
2023	158	+31.6%
2024	140	-11.4%

Source: Prepared directly by the Implementing Entity.

Analysis of official records showed that 120 accidents were reported in 2022, a year in which mobility restrictions resulting from the pandemic can be considered to have stabilized. In 2023, the figure rose to 158, representing a 31.6% increase. The greater exposure to risk resulting from the increased traffic flow is a determining factor in the observed increase.

In 2024, 140 accidents were recorded, showing an 11.4% decrease compared to the previous year, indicating that the reduction does not represent a full recovery to previous levels.

From a comparative perspective, while a decrease is observed in 2024, the total number of accidents remains higher than that recorded in 2022, indicating that a sustained downward trend has not yet been achieved. This behavior suggests that the increase observed in 2023 was not an isolated phenomenon, but possibly linked to structural factors such as:

- ✓ Post-pandemic economic recovery
- ✓ Increased interprovincial traffic
- ✓ Greater circulation of heavy freight transport
- ✓ Increase in the regional vehicle fleet

Likewise, the partial reduction in 2024 could be related to increased enforcement operations implemented by the Peruvian National Police and SUTRAN, although the data do not yet show a sustained structural decrease.

Table 2

Main causes of accidents (Average 2022–2024)

Cause	Percentage
Speeding	38%
Driver negligence	27%
Lane invasion	18%
Climatic conditions	10%
Mechanical failures	7%

Source: Prepared directly by the Implementing Entity.

The analysis of the causes reveals a significant concentration of factors associated with human behavior. Speeding accounted for 38% of cases, followed by reckless driving (27%) and lane invasion (18%). These results are consistent

with those noted by Gonzales (2021), who identified human behavior as the main risk factor on national highways.

Regarding the main causes, speeding was the leading cause in the three years analyzed. This finding coincides with academic studies published in indexed journals that identify driver behavior as the main risk factor. From a physical and mechanical standpoint, speed exponentially increases the kinetic energy involved in an impact, which raises the severity of injuries and the probability of death. On long straight stretches, characteristic of the Juliaca–Arequipa route, the perception of safety can lead drivers to exceed the speed limits.

Driver negligence includes reckless maneuvers, improper overtaking, distraction, fatigue, and driving under time pressure. This factor reflects deficiencies in road safety education, a culture of prevention, and risk perception.

Invading the opposite lane is directly associated with head-on collisions, one of the most lethal types of accidents. The absence of physical barriers on certain stretches of road increases the likelihood of these types of events. While weather conditions are a factor, in high Andean regions, heavy rain, fog, hail, and ice can act as aggravating factors when combined with excessive speed. Mechanical failures represent the smallest percentage of accidents, but they can be related to inadequate maintenance of interprovincial and freight transport vehicles. Head-on collisions and rollovers were the most frequent types of accidents and those that resulted in the highest number of fatalities. This pattern is consistent with previous research conducted in the high Andean regions (Flores, 2019), where geographical and climatic conditions exacerbate the impacts.

From a comparative perspective, the annual variation demonstrates that control policies have a limited impact. A comprehensive strategy is needed, including ongoing road safety education, improved signage, infrastructure maintenance, and continuous monitoring using technology.

From an analytical perspective:

- ✓ Excessive speed exponentially increases the severity of the impact.
- ✓ Lane invasion is primarily associated with head-on collisions.
- ✓ Reckless driving includes dangerous maneuvers, improper overtaking, and distraction.

Weather conditions (10%) and mechanical failures (7%) have a lower percentage incidence; however, in high Andean areas like this route, adverse weather conditions can act as aggravating factors when combined with excessive speed.

The results are consistent with the "Safe System" model promoted by the World Health Organization, which states that human error is inevitable, but the road system must be designed to minimize fatal consequences.

The high incidence of the human factor demonstrates that the current infrastructure does not adequately compensate for driver errors. This suggests the need for:

- ✓ Physical lane separators.
- ✓ Intelligent speed control systems.
- ✓ Enhanced signage in critical areas.
- ✓ Periodic road safety audits.

Overall, 83% of accidents are due to direct human factors, confirming the predominance of behavioral factors over technical or environmental factors.

These results indicate a fluctuating trend, not a sustained structural reduction. While driver behavior is the main causal factor, the severity of accidents is high due to the predominant types. Therefore, current policies show partial but insufficient effects. The accident rate is due to systemic factors related to mobility, infrastructure, and road safety culture.

DISCUSSION

The results obtained in this research show that 83% of the accidents recorded on the Juliaca–Arequipa route during the period 2022–2024 are linked to factors directly associated with human behavior, notably speeding (38%), driver negligence (27%), and lane invasion (18%). This predominance of behavioral factors opens the discussion about the structural determinants that could be incentivizing or facilitating such risky behaviors, including the persistence of informality in interprovincial passenger transport.

Informality in transport can be defined as the provision of services without fully complying with the legal, technical, and administrative requirements established by the State, including authorizations, technical inspections, mandatory insurance, and labor regulations. In Peru, the supervision of interprovincial transport falls to SUTRAN and the National Police of Peru. However, in high-traffic corridors like Juliaca–Arequipa, the vast territory and the dynamics of commerce make it difficult to continuously monitor all vehicles in circulation.

From an economic perspective, informal transportation operates under a system of direct competition for passengers, where the driver's income depends on the

number of trips made and the speed with which routes are completed. This economic incentive can generate risky behaviors such as speeding and improper passing, variables that coincide with the main causes identified in this study. Thus, the pressure to maximize income in a competitive environment without strict regulation can translate into greater exposure to road risks.

Furthermore, informality is often associated with long working hours and a lack of oversight regarding rest periods. Driver fatigue is an internationally recognized predictor of human error, decreased reaction time, and unintentional lane crossings. On high-altitude Andean routes like the one studied, characterized by long straight stretches and variable weather conditions, fatigue can significantly increase the likelihood of head-on collisions and rollovers, which proved to be the most severe types of accidents in this research.

Another relevant aspect is vehicle maintenance. Although mechanical failures account for 7% of the direct causes recorded, informality can indirectly increase the risk by reducing the frequency of technical inspections and preventive maintenance. Vehicles with worn brake systems, tires in poor condition, or structural deficiencies increase the probability of loss of control, especially in adverse weather conditions.

From the "Safe System" approach, promoted by the World Health Organization, road safety depends on the interaction between safe users, safe vehicles, safe infrastructure, and efficient institutional management. Informality weakens at least three of these pillars: it compromises user training and oversight, reduces the guarantee of technically sound vehicles, and hinders effective enforcement. Consequently, accident rates should not be interpreted solely as the result of individual decisions, but rather as a manifestation of structural flaws in the transportation system.

Comparatively, studies conducted in Latin America indicate that transportation systems with high levels of informality exhibit higher accident rates per kilometer traveled, due to economic incentives that prioritize speed over safety and persistent regulatory weaknesses. In this regard, the results obtained on the Juliaca–Arequipa route are consistent with regional evidence.

However, it is important to clarify that this research did not directly measure the proportion of informal vehicles involved in accidents. Therefore, the established relationship should be understood as a theoretical association based on the correlation between the predominant causes and the structural characteristics of informal transportation. Future research could incorporate specific variables such as type of operating company, contractual formality, vehicle age, and driver employment status to establish more precise statistical analyses.

In summary, the informality of passenger transportation can be considered an indirect structural factor that contributes to the persistence of risky behaviors on the Juliaca–Arequipa route. Addressing this issue requires comprehensive policies that include gradual formalization, institutional strengthening, incentives for regulatory compliance, and mandatory training programs for interprovincial drivers. Without reducing informality, isolated enforcement strategies will hardly achieve a sustained decrease in accidents.

CONCLUSIONS

The analysis shows a significant increase in 2023 compared to 2022, followed by a slight reduction in 2024. In cumulative terms, 418 accidents were recorded over the three years ($120 + 158 + 140$). The annual average is approximately 139 accidents per year. 2023 represents 37.8% of the cumulative total for the period, making it the year with the highest incidence. This trend suggests that accident rates on the route are sensitive to economic and mobility variations, indicating that risk exposure is a determining factor.

Speeding and driver negligence were the main causes of traffic accidents on the Juliaca-Arequipa route. These were followed by head-on collisions and rollovers, resulting in an increase in the number of fatalities and highlighting the severity of accidents on this interprovincial road.

Human error predominates as the main cause of accidents. It is recommended to strengthen enforcement policies, promote road safety education and investment in road infrastructure, and implement technological systems for the control and sustained reduction of traffic accidents.

The findings confirm that accidents on the Juliaca–Arequipa route are primarily due to behavioral factors. This result aligns with the road safety model based on the “Safe System” approach, promoted by the World Health Organization, which recognizes that human error is inevitable, but deaths and serious injuries can be prevented through safe infrastructure, safe vehicles, and effective enforcement.

The informal nature of passenger transport can be considered an indirect structural factor that encourages risky behavior due to economic pressure, competition for demand, and limited technical supervision. Isolated enforcement policies show only partial effects; a comprehensive strategy is required that includes the progressive formalization of transport, mandatory driver training, institutional strengthening, and investment in safe infrastructure. From the Safe System perspective, the sustainable reduction of accidents requires simultaneous intervention in regulation, infrastructure, enforcement, and road safety culture.

While a slight reduction was observed in 2024, it was not statistically sufficient to confirm a sustained downward trend. This suggests that current enforcement measures have a limited impact if they are not integrated with ongoing road safety education and structural improvements.

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CONTAMINATION OF THE TOROCOCHA RIVER AND DESIGN OF A FLUVIAL RESTORATION STRATEGY THROUGH NATURE-BASED SOLUTIONS AND ECOLOGICAL CORRIDORS

Mendoza Mendoza, Nilson Aníbal

ABSTRACT

The Torococha River, located in the city of Juliaca (Coata–Lake Titicaca basin), has been progressively degraded by unplanned urbanization, domestic discharges, solid waste dumping, and encroachment on riparian buffer zones, resulting in hydromorphological deterioration, public health risks, and loss of ecosystem services. This review paper synthesizes recent scientific and regulatory evidence on: (i) typical pressures and impacts affecting high-Andean urban rivers; (ii) assessment tools (water quality indices, bioindicators, and performance criteria); and (iii) restoration strategies with emphasis on ecological corridors and nature-based solutions (NbS) compatible with budgetary and climatic constraints. A phased intervention framework is proposed for the Torococha River that integrates source control (sanitation and solid waste management), riparian recovery (bioengineering, revegetation, and public spaces), constructed wetlands, and adaptive monitoring using physical-chemical, biological, and social indicators. The approach aligns with Peru's Environmental Quality Standards for Water (ECA-Water) and the IUCN Global Standard for NbS, prioritizing co-benefits related to urban health, climate resilience, and participatory governance.

Keywords: *urban river; fluvial restoration; ecological corridors; nature-based solutions; constructed wetlands.*

INTRODUCTION

The use of or Urban rivers concentrate anthropogenic pressures—wastewater discharges, contaminated stormwater runoff, channelization, and loss of riparian vegetation—that reduce their ecological quality and exacerbate public health risks. Globally, in 2022, approximately 42% of domestic wastewater was not safely treated prior to discharge, illustrating the scale of the sanitation challenge in urban and peri-urban areas (UN-Habitat & WHO, 2024).

In high-Andean systems, impacts may be amplified by low temperatures, high solar radiation, pronounced seasonality, and infrastructure limitations. In the Altiplano, the Coata basin and Lake Titicaca receive inputs of nutrients, pathogens, heavy metals, and solid waste associated with urban and industrial discharges and incomplete waste management and sanitation systems (Ocola & Laqui, 2017).

The international literature demonstrates that urban river restoration is most effective when it combines source control, physical channel recovery, and integrated green–blue solutions embedded in urban planning and local governance. In Latin America, there is growing interest in re-naturalization, ecological corridors, and green infrastructure as planning instruments, though implementation and monitoring gaps persist (Pradilla & Hack, 2024).

The objective of this article is to update the state of the art on Torococha River contamination (Juliaca) and to consolidate a restoration proposal based on ecological corridors and NbS, including an indicator framework and an implementation roadmap.

METHODOLOGY

A narrative review with elements of systematic reporting was conducted following PRISMA 2020 recommendations to ensure transparency in source identification and selection (Page et al., 2021). Bibliographic databases and open-access repositories were consulted (MDPI, SpringerOpen/BMC, WHO/PAHO, IUCN, UN-Habitat) as well as Peruvian repositories (ANA, MINAM, universities), prioritizing documents from 2015–2025.

Inclusion criteria were: (i) studies on urban rivers and fluvial restoration; (ii) evidence on NbS applied to urban drainage, constructed wetlands, riparian buffer zones, and ecological corridors; (iii) studies in high-Andean or cold-climate contexts when available; and (iv) relevant regulations and technical guidelines for Peru. Duplicates, literature lacking minimum methodological support, and documents without full-text availability were excluded.

The synthesis was organized around: characterization of the Torococha River; sources and evidence of contamination; regulatory framework; restoration strategies and supporting evidence; and an integrated proposal for the Torococha River with performance indicators and implementation phases.

THEMATIC DEVELOPMENT

Characterization of the Torococha river

The Torococha River traverses the city of Juliaca from west to east, draining toward the Coata basin and ultimately connecting with the Lake Titicaca system. It originates in the Chullunquiani sub-watershed (northwest of the city), spans approximately 18 km in total length, and includes an urban reach of approximately 3 km in a covered channel from the city center to the Circunvalación Avenue bridge; beyond this point, the river continues as an open channel to its confluence with the Coata River (Ocola & Laqui, 2017).

From a territorial planning perspective, the Torococha River represents a potential axis for urban green infrastructure (linear parks, ecological connectivity, and active mobility), offering documented health benefits associated with urban green spaces (World Health Organization Regional Office for Europe, 2016).

Description and assessment of contamination

Local evidence consistently indicates that contamination of the Torococha River is dominated by domestic wastewater inputs discharged through illegal connections and direct dumping, supplemented by urban stormwater runoff (sediments and contaminants), solid waste disposal in the channel, and diffuse inputs intensified during the rainy season (Coaquira, 2017; Ocola & Laqui, 2017). This pattern is explained by Juliaca's accelerated urban expansion and the use of the fluvial system as a receiving body for municipal and informal discharges (Avila, 2017; Yana, 2014).

Relevant concentrations of heavy metals in water and sediments have been reported in urban sectors of the Titicaca–Coata basin, underscoring the need to assess not only organic contamination but also risks associated with persistent contaminants (Moreno, 2017). For the Torococha River, available studies primarily describe elevated organic matter loads and indicator microorganism concentrations, consistent with predominant domestic discharges (Yana, 2014; Ocola & Laqui, 2017). A consistent finding is the low dissolved oxygen availability and organic overload associated with municipal wastewater; for instance, it has been documented that a majority fraction of the BOD₅ load in the system originates from the effluent of the Juliaca oxidation ponds, evidencing operational/technological limitations in treatment that may be further exacerbated by climatic conditions (Ocola & Laqui, 2017). To integrate multiple parameter readings, some regional studies have employed composite indices (e.g., CCME-WQI and adaptations), complementing physicochemical and microbiological variables with pressure and land-use data (Gutiérrez, 2018).

The degradation of the Torococha River poses public health risks through pathogen exposure and urban environment deterioration (odors, waste, loss of landscape value), as well as downstream impacts acting as a pressure source on the Coata River and the Lake Titicaca system, particularly through nutrient loading (Avila, 2017). In this context, the restoration literature warns that interventions focused solely on aesthetic improvements tend to be ineffective unless the pollutant load is first reduced: biological recovery may be limited when contamination persists, even when channel morphology is improved (Hörchner et al., 2025). Therefore, the strategy must prioritize source control and load reduction as enabling conditions for any riparian habitat restoration.

Regulatory framework and compliance criteria

In Peru, the Environmental Quality Standards (ECA) for Water were compiled and updated through Supreme Decree No. 004-2017-MINAM, which defines use categories and subcategories with physicochemical, microbiological, and metal parameters, among others (Ministerio del Ambiente, 2017).

For a Torococha River restoration strategy, the ECA standards are useful as quality objective references for prioritized reaches (e.g., recreational uses or aquatic conservation, as applicable) and as the basis for a monitoring plan with progressive targets (short-, medium-, and long-term).

Regulatory framework and compliance criteria

Nature-based solutions (NbS) seek to address socio-environmental challenges through the protection, sustainable management, and restoration of ecosystems, generating simultaneous benefits for biodiversity and human well-being. The IUCN Global Standard for NbS establishes 8 criteria to ensure effectiveness, economic viability, inclusive governance, and adaptive management (IUCN, 2020). In riparian environments, convergence exists between fluvial restoration and NbS, though with differences in objectives and metrics. A recent synthesis proposes clarifying these boundaries and selecting indicators consistent with the type of intervention (Carbonari & Solari, 2025).

Riparian ecological corridors combine biological connectivity with urban functions (recreation, active mobility, shade, and thermal mitigation). In Colombia, the integration of rivers and primary ecological structure into territorial planning instruments has driven re-naturalization projects, offering replicable lessons for intermediate cities in Latin America (Pradilla & Hack, 2024). Operationally, the prioritization of restoration practices in urban rivers can be supported by multi-criteria methodologies that combine criticality (risk/impact) and 'opportunity layers' (space availability, synergies with infrastructure, green connectivity). A recent

example proposes the Criticality Index for Watershed Restoration and opportunity layers to rank interventions and justify decisions (Lima et al., 2024).

Constructed wetlands and buffer zones are effective NbS for removing nutrients, organic matter, and pathogens, as well as attenuating flow peaks. Recent reviews highlight their role as an efficient technology and their potential for adaptation in diverse contexts, including high-Andean sites where macrophyte selection, hydraulic retention time, and maintenance are critical (Guo, 2025).

Reducing waste in rivers depends primarily on source prevention (collection, recycling, education, and municipal enforcement). Retention barriers and capture devices may be useful as transitional measures at critical points, provided that logistics for removal and adequate disposal are in place to avoid merely displacing the problem.

Regulatory framework and compliance criteria

The proposal is structured around four principles: (1) source control (sanitation + solid waste) as an enabling condition; (2) riparian restoration and ecological connectivity; (3) NbS for treatment and hydrological buffering; (4) adaptive governance and monitoring with transparency.

To guide more effective management of the Torococha River, a functional segmentation of the channel into three reaches (A, B, and C) is proposed, defined by changes in dominant pressures and territorial conditions (headwaters/peri-urban–urban core–outfall). This approach enables alignment of measures with the type of impact, prioritization of interventions, and outcome monitoring with verifiable indicators. Table 1 summarizes the intervention logic by reach (pressures–objective–measures–indicators).

Table 1

Prioritization of interventions by reach in the Torococha River

Reach	Dominant Pressures	Objective	Key Measures	Minimum Indicators
A. Headwaters	Erosion, loss of vegetation cover, incipient encroachment, isolated discharges	Protect headwaters and reduce sediment loads	Riparian buffer zone + erosion control + revegetation + elimination of discharges	% buffer recovered; TSS/turbidity; % cover; No. of discharges eliminated
B. Urban Core	Illegal connections, wastewater, solid waste, unstable embankments	Cut sources and establish a safe urban corridor	Cadastre/closure of connections + improved sanitation operation + continuous cleanup + bioengineering + pilot reach	E. coli; BOD/COD; N–P; No. connections; tons/month waste; No. stabilized points
C. Outfall to Coata	Sediment/waste transport, habitat loss	Buffer pollutant loads and restore habitat	Constructed wetlands/buffers + sediment/solid traps + riparian restoration + biological monitoring	Removal (%) TSS/BOD/N/P; m ³ sediment; biotic index/birds

Note. TSS = total suspended solids; BOD = biochemical oxygen demand; COD = chemical oxygen demand; N–P = nitrogen and phosphorus (nutrients).

To prevent purely cosmetic restoration, a monitoring matrix is proposed with indicators and targets across four dimensions: water quality, biota, hydromorphology, and social-institutional management, consistent with restoration and adaptive management frameworks (SER, 2019; UN-Habitat & WHO, 2024; Shao, 2025). Monitoring frequency is defined by parameter dynamics: monthly–bimonthly (water), quarterly–biannual (biota), and biannual–annual (hydromorphology). Targets are indicative and should be adjusted according to baseline data and current regulations (MINAM, 2017).

International evidence highlights that social appropriation and community ownership improve the sustainability of urban restoration projects (maintenance, surveillance, and policy continuity). In Japan, a study on the expansion of community activities following urban river restoration underscores practical mechanisms (local committees, seasonal events, and public reporting) to cultivate a sense of ownership and support climate adaptation (Itsumi et al., 2025). This component is particularly relevant in Juliaca to prevent the reoccupation of riparian areas and recurrence of wastewater discharges.

Table 2

Indicators, frequency, targets, and supporting evidence for monitoring the restoration of the Torococha River

Dimension	Indicators	Frequency	Target (Guidance)	Reference Study
Water	BOD ₅ /COD; TSS; N-P; E. coli	Monthly–bimonthly	30% improvement in 12 months; improvement by reach	Wang, 2023; Bakri et al., 2023; Kasprzyk, 2025
Water	Metals (as applicable by risk)	Quarterly–biannual	Progressive compliance	MINAM, 2017
Biota	Macroinvertebrates (index)	Quarterly–biannual	Positive trend	Magallón-Ortega et al., 2021; Mureithi et al., 2025
Biota	Riparian vegetation (cover/continuity)	Quarterly–biannual	Increase cover	in Qu et al., 2025
Hydromorphology	Critical points; stability/erosion	Biannual	Decrease critical points/erosion	in Hajdukiewicz, 2017
Social-Management	Discharges eliminated; waste removed; community participation	Monthly–quarterly	Zero discharges prioritized reaches; permanent program	in Deltares, 2025; Shao et al., 2025

Note. Targets adjustable based on baseline data, seasonality, and current standards (MINAM, 2017).

The recovery of the Torococha River must be implemented in phases to: (a) prioritize pressures before investing in infrastructure; (b) combine source control with physical interventions; and (c) sustain results through monitoring and adaptive management (Robins, 2025; Stoffels et al., 2024). It is recommended to formalize operational coordination among the municipality, the water utility (EPS), and competent authorities (Autoridad Nacional del Agua; OEFA), in accordance with water governance principles (OECD, 2015), and to structure monitoring with a baseline and verifiable indicators (FAO, 2024).

Table 3

Phased roadmap: objectives, actions, and supporting literature

Phase (Timeline)	Operational Objective	Key Actions	Supporting Studies
Phase 0 (0–6 months) Startup and Rapid Control	Define the problem and regain control of the critical reach	(i) Rapid diagnosis of point and diffuse sources. (ii) Mapping and georeferencing of discharges and connections. (iii) Solid waste cleanup and removal with proper disposal. (iv) Institutional agreements (municipality–utility–ANA/OEFA–university–community boards). (v) Design of monitoring plan (baseline, indicators, sampling points and frequency).	Robins, 2025; Ferreira da Silva et al., 2024
Phase 1 (6–18 months) Stop the 'Hemorrhage' + Pilot Reach	Rapidly reduce sanitary impact and demonstrate tangible results	(i) Closure/control/diversion of critical discharges. (ii) Operational improvements to sanitation infrastructure (overflow control, maintenance, connections). (iii) Pilot linear park in a demonstration reach. (iv) NbS pilots: constructed wetland and/or buffer zones.	Kaur et al., 2026; IUCN, 2020
Phase 2 (18–36 months) Scaling the Ecological Corridor	Transition from pilot to a continuous, resilient system by reach	(i) Scale ecological corridor to prioritized reaches. (ii) Riparian revegetation and bioengineering for stabilization/erosion control. (iii) Gradual optimization of treatment and operations based on monitoring data.	Ayala-Torres et al., 2025; Tisserant et al., 2021; Robins, 2025
Phase 3 (>36 months) Sustain and Continuously Improve	Prevent regression and consolidate financing, monitoring and adaptive management	(i) Routine maintenance (cleanup, dredging, vegetation replacement). (ii) Sustainable financing (environmental canon/partnerships/reach adoption; MERESE-type instruments where applicable). (iii) Long-term monitoring with verification/auditing. (iv) Adaptive management + public reporting (dashboard).	Stoffels et al., 2024; MINAM, 2017

CONCLUSIONS

The evidence reviewed demonstrates that the Torococha River exhibits a consistent pattern of degradation typical of High-Andean urban rivers, dominated by untreated domestic discharges, illegal connections, urban stormwater runoff, and solid waste, with sanitary impacts, loss of riparian functions, and downstream pressures on the Coata–Lake Titicaca basin.

Available studies describe organic overload and microbiological contamination as critical signals, and suggest complementing assessments with an integrated reading of territorial pressures and composite indices, especially in contexts with marked seasonal variability.

The literature agrees that restoration is effective only when the sequence is respected: first, source control, then habitat recovery: NbS and aesthetic improvements do not compensate for persistent discharges and may produce only aesthetic results if the pollutant load is not reduced first.

The proposed strategy integrates green–grey measures (sanitation and waste management), riparian restoration (bioengineering and revegetation), constructed wetlands/buffer zones, and ecological corridors, aligning with Peru's ECA-Water standards and international NbS criteria to maximize urban co-benefits (health, climate resilience, and habitability).

The functional segmentation by reach (headwaters–urban core–outfall) enables prioritization of actions based on dominant pressures and sustains implementation through an indicator matrix (water, biota, hydromorphology, and management), calibrated with baseline data and progressive targets by reach.

Long-term viability depends on institutionalizing inter-agency agreements, securing financing for operation and maintenance, and sustaining monitoring with public reporting and adaptive management to prevent recurrence of discharges and reoccupation of riparian areas.

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RELATIONSHIP BETWEEN PERCEPTION OF ACADEMIC PERFORMANCE AND METACOGNITION IN UNIVERSITY STUDENTS

Salluca Condori, Yovana

ABSTRACT

Academic performance, influenced by metacognitive skills, is a crucial aspect of student education; In this context, this research aimed to determine the relationship between perceived academic performance and metacognition in students at the Higher Pedagogical Institute in Puno, Peru. The research applied a quantitative-descriptive, correlational, transactional, and non-experimental approach. The sample consisted of 62 students using non-probability sampling. The results revealed a significant relationship between both variables, with a Spearman's Rho correlation coefficient of 0.994 ($p = 0.000$). Furthermore, 61.3% of participants felt "almost always" satisfied with their academic performance and their metacognition. The memory and comprehension dimensions showed high levels of use of metacognitive strategies (54.8% and 59.7%, respectively). It is concluded that the development of metacognitive skills should be encouraged to achieve effective and sustainable learning.

Keywords: metacognitive strategies; university students; metacognitive skills; academic performance; metacognition.

INTRODUCTION

Academic performance is a fundamental aspect of student education. It represents the value assigned to their learning outcomes in a specific discipline, compared to the level of knowledge expected among their peers (Gutiérrez et al., 2021). This performance is not limited to grades; it is also closely related to various skills, among which metacognitive skills stand out (López et al., 2023).

From the perspective of Swanson et al. (2024), students' academic performance improves by providing them with reflective opportunities that allow them to develop their metacognition independently. According to Cancino (2024), metacognitive strategies aim to regulate and control learning, which facilitates more

effective and accessible learning. Salazar and Cáceres (2022) also highlight that these strategies are related to action; they involve the use of resources that allow students to know how to do and process information. Furthermore, they include awareness as a regulatory mechanism that seeks to achieve meaningful learning, improve self-esteem, and foster a sense of ownership over one's own knowledge.

In this sense, Drigas and Mitsea (2020) argue that metacognition is the most important competency of the 21st century. In their study, they define eight pillars that support this skill, which are organized according to a hierarchical model of knowledge. From their perspective, cognitive and metacognitive skills develop progressively, depending on the effort that each person invests. Furthermore, they highlight those certain cognitive functions, such as attention and working memory, appear to have a more significant impact than others.

Consequently, the arguments presented regarding the impact of metacognitive skills on academic performance, as well as the personal and professional growth of students, highlight the need to integrate these skills into the educational process. According to Velásquez (2024), this implies that teachers must incorporate metacognition into their teaching methods. To achieve this, it is essential that teachers also develop metacognitive skills as part of their professional training, as this practice should not be exclusive to students.

In this context, the Higher Pedagogical Institute of Puno is dedicated to the training of future teachers, who will play a crucial role in developing the metacognitive skills of their future students. To achieve this, they must not only transmit knowledge but also cultivate skills that foster independent and reflective learning. Understanding the relationship between the perception of academic performance and metacognitive skills is essential for optimizing education, promoting meaningful learning, and identifying areas for improvement in educational quality. This analysis will provide valuable information for the design of educational strategies that strengthen the academic performance and comprehensive development of the current students that will become future teachers. Therefore, the present research aims to determine this relationship in the group of students in the Social Sciences area of the Puno Higher Pedagogical Institute, Peru.

METHOD

This research applied a quantitative-descriptive, correlational, transactional, and non-experimental approach. The study was conducted at the Higher Pedagogical Institute located in the region of Puno in Peru. The aim was to determine the relationship between perceptions of academic performance and metacognition.

Participants

The study population consisted of all students enrolled in the Social Sciences program at the Higher Pedagogical Institute in Puno. The sample was selected using a non-probability convenience sample, gathering 62 students.

Hypotheses

The following hypotheses were formulated:

Null Hypothesis (H0): There is no significant relationship between students' perceptions of academic performance and metacognition in students studying social sciences at the Higher Pedagogical Institute in Puno.

Alternative Hypothesis (H1): There is a significant relationship between perceived academic performance and metacognition in social science students at the Higher Pedagogical Institute in Puno.

Alternative Hypothesis (H2): There is a significant relationship between perceived academic performance and memory metacognition in social science students at the Higher Pedagogical Institute in Puno.

Alternative Hypothesis (H3): There is a significant relationship between perceived academic performance and attention metacognition in social science students at the Higher Pedagogical Institute in Puno.

Alternative Hypothesis (H4): There is a significant relationship between perceived academic performance and metacognition of comprehension in social science students at the Higher Pedagogical Institute in Puno.

Alternative Hypothesis (H5): There is a significant relationship between perceived academic performance and thinking metacognition in social science students at the Higher Pedagogical Institute in Puno.

Operationalization of variables

Two variables were studied: perception of academic performance and metacognition. The measurement scale used was ordinal. Table 1 details the dimensions, indicators, and descriptions of each variable.

2.1 Instruments

A survey was used to collect the data, and the instruments consisted of two questionnaires: one measuring perceived academic performance and the other metacognition. The questions were designed according to a Likert scale, with a single option of five possible answers (never, almost never, sometimes, almost

always, and always). The results showed the Cronbach's alpha coefficient of 0.91 for the questionnaire on perceived academic performance and 0.90 for the metacognition questionnaire, indicating a high degree of reliability above 0.70.

2.2 Procedure

Permission was obtained from the academic authorities of the Faculty of Social Sciences of the Higher Pedagogical Institute in Puno to conduct the study. Informed consent was obtained from all participating students, who guaranteed the confidentiality and privacy of their personal information.

Both questionnaires were administered online using Google Forms. Once completed, the responses were tabulated for analysis using descriptive statistics, with the calculation of absolute and relative frequencies corresponding to each response given by the participants. Inferential statistical analysis was also used to test the hypotheses formulated regarding the relationships between the variables of perceived academic performance and the metacognitive dimensions (memory, attention, thinking, and comprehension) using Spearman's Rho correlation coefficient. The data was processed using SPSS version 29.0 software.

RESULTS

The data shown in table 1 indicate that the majority of students in the social sciences area of the Higher Pedagogical Institute in Puno have a favorable perception of their academic performance, which is encouraging for their educational development. This is evidenced by the fact that, although none indicated the optimal option ("always"), it suggested that it is possible to have continuous improvement; at the same time, a considerable number (61.3%) stated that they were "almost always" satisfied, which is a positive indicator of the general perception among students. Regarding the dimensions of students' perception of academic performance, different levels of satisfaction are reflected. In the procedural dimension, no students report a perception of "never," indicating that all have at least some awareness of their study strategies. However, 25.8% of participants indicated that they "almost never" use effective strategies, which could indicate a lack of confidence or knowledge in this area. Another 19.4% mentioned that they "sometimes" do so, while the majority, represented by 54.8%, stated that they are "almost always" able to follow instructions, learn new skills, and employ planning strategies to organize their time.

In the attitudinal dimension, as in the procedural dimension, no students indicated a perception of "never." However, 12.9% mentioned that they "almost never" feel motivated or satisfied with their learning. A more significant percentage, 40.3%, indicated that they "sometimes" feel motivated and interested in learning

innovative things, completing their assignments, and actively participating in class. Meanwhile, 32.3% stated that this "almost always" happens to them, and 14.5% reported that students are "always" having a positive attitude, which is an encouraging indicator for the educational environment.

Regarding the social dimension, 6.5% of students indicated that they "never" participate in group activities or social interactions related to their learning, which could be a cause for concern, given that social interaction is essential for collaborative learning. 6.5% also mentioned that they "almost never" participate, while a significant majority (59.7%) indicated that they "sometimes" participate in academic social activities. Likewise, 27.3% stated that they "almost always" interact socially in the educational context; however, none reported that they "always," so it would be good to consider these as areas for improvement in collaboration and peer support.

Finally, in the autonomous dimension, no students reported a perception of "never," which is positive. However, 12.9% indicated that they "almost never" manage their own learning without supervision. The majority (61.3%) stated that they are "almost always" autonomous, which is a positive indicator of their ability to self-assess and take initiative in their learning. 19.3% mentioned being autonomous "sometimes," and 6.5% indicated that they are "always" autonomous. These results suggest that, despite a good level of autonomy, there is still room to foster this skill.

Table 1

Student perceptions of academic performance and its dimensions.

	Perception academic performance		of Dimensions of perception of academic performance							
			Procedural		Attitude		Social		Autonomous	
	fr	%	fr	%	fr	%	fr	%	fr	%
Never	0	0 %	0	0 %	0	0 %	4	6,5 %	0	0 %
Almost never	8	12,9 %	16	25,8 %	8	12,9 %	4	6,5 %	8	12,9 %
Sometimes	16	25,8 %	12	19,4 %	25	40,3 %	37	59,7 %	12	19,3 %
Almost always	38	61,3 %	34	54,8 %	20	32,3 %	17	27,3 %	38	61,3 %
Always	0	0 %	0	0 %	9	14,5 %	0	0 %	4	6,5 %

Note: Own elaboration

Regarding the results on metacognition, they reflect the perception of the students who participated in the study regarding their ability to self-regulate and reflect on their own learning. Table 1 shows that none reported a perception of "never," indicating that all participants have at least some levels of awareness in

this regard. Although 12.9% indicated that they "almost never" and 25.8% mentioned that they "sometimes," the majority (61.3%) stated that they are "almost always" aware of their learning processes and use metacognitive strategies to regulate their study. Despite this, none indicated a perception of "always," and this is something that must be worked on to improve their practice in how they learn, think, and solve problems. Regarding the results on the dimensions of metacognition, in the case of memory, no student indicated that they "never" use metacognitive strategies, a favorable element because it means that all participants have at least some awareness of their ability to remember information. However, 25.8% reported that they "almost never" and 19.4% that they "sometimes" use strategies to improve their memory. Nevertheless, more than half (54.8%) stated that they "almost always" use metacognitive techniques to recall information they learned a long time ago, such as historical facts or mathematical formulas. Therefore, they are aware of their memorization processes and apply effective strategies in this area.

In the attention dimension, as with memory, no students leaned toward the "never" category. However, 12.9% indicated that they "almost never" manage to concentrate or use strategies to maintain their attention while studying. Furthermore, a significant 40.3% mentioned that they "sometimes" struggle to focus on a single task when other activities or people around them could distract them, indicating variability in their ability to sustain attention. However, 32.3% stated that they "almost always" use strategies to focus, and 14.5% reported doing so "always." These results show that, although many students can focus and apply strategies, a considerable number still face challenges in this area.

In the comprehension dimension, there were again no "never" responses. 6.5% indicated that they "almost never" reflect on what they have learned or use strategies to better understand the content. 6.5% also mentioned that they "sometimes," which is low compared to other indicators. However, a notable 59.7% stated that they "almost always" use metacognitive techniques to improve their understanding of the material, and 27.3% reported doing so "always." These findings indicate a strong tendency among students to reflect on their learning and apply effective strategies in this dimension.

Finally, in the thinking dimension, there were no "never" responses. 12.9% indicated that they "almost never" critically evaluate the information received or apply critical thinking strategies. 25.8% mentioned "sometimes," while 54.8% stated that they "almost always" use metacognitive strategies to solve problems and frequently come up with new ideas. However, only 6.5% indicated that they "always" do so. These results indicate that, although the majority demonstrate a

good ability to think critically and apply metacognitive strategies, there is room for improvement in this area.

Table 2

Student perceptions of metacognition and its dimensions.

	Metacognition		Dimensions of metacognition							
			Memory		Attention		Comprehension		Thinking	
	fr	%	fr	%	fr	%	fr	%	fr	%
Never	0	0 %	0	0 %	0	0 %	0	0 %	0	0 %
Almost never	8	12,9 %	16	25,8 %	8	12,9 %	4	6,5 %	8	12,9 %
Sometimes	16	25,8 %	12	19,4 %	25	40,3 %	4	6,5 %	16	25,8 %
Almost always	38	61,3 %	34	54,8 %	20	32,3 %	37	59,7 %	34	54,8 %
Always	0	0 %	0	0 %	9	14,5 %	17	27,3 %	4	6,5 %

Note: Own elaboration

At the inferential level, Pearson's correlation coefficient (r) was applied to test the hypothesis, establishing a significance level of 5%. Regarding the overall correlation between metacognition and academic performance, as shown in table 4, the Pearson coefficient was 0.994, indicating an extremely strong and positive relationship. This means that as students develop metacognitive skills (such as planning, monitoring, and regulating their own learning), their academic performance tends to improve significantly. A significance level (Sig.) of 0.000 indicates that this relationship is statistically significant, meaning that it is highly unlikely that this correlation occurred by chance. This constitutes evidence supporting the alternative hypothesis (H1) and rejecting the null hypothesis (H0). Regarding the correlation between memory-related metacognition and academic performance, the Pearson coefficient had a high result of 0.930. This means that students who are more aware and effective in their memory strategies tend to achieve better academic results. As in the general case, the significance (Sig.) value of 0.000 indicates statistical significance, reinforcing the idea that metacognitive memory skills are crucial for academic success, thus accepting the alternative hypothesis (H2).

The same is happening to the attention dimension, the correlation for attention is also 0.930, indicating a strong positive relationship with academic performance. This suggests that students who are more effective in directing and maintaining their attention during learning tend to perform better academically. Again, the significance (Sig.) value of 0.000 confirms statistical significance, thus accepting the alternative hypothesis (H3).

The correlation for the comprehension dimension is slightly lower (0.750) but still strong and positive, indicating that students who have good control over their thinking processes also tend to perform well academically. The significance level (Sig.) is significant (0.000), which reinforces this conclusion and constitutes evidence to accept the alternative hypothesis (H4).

Finally, the correlation for the thinking dimension is 0.817, which is strong, although slightly lower compared to the other dimensions evaluated. This indicates a positive relationship between metacognitive skills related to comprehension and academic performance; however, it may indicate that other factors influence this specific dimension. The significance level (Sig.) is also significant (0.000), confirming the statistical significance, thus accepting the alternative hypothesis (H5).

Table 3

Relationship between perceived academic performance and different dimensions of metacognition.

		Academic Performance	
Metacognition	Pearson Correlation	,994**	
	Sig. (2-tailed)	,000	
	N	62	
Memory Attention	Pearson Correlation	,930**	
	Sig. (2-tailed)	,000	
	N	62	
Comprehension	Pearson Correlation	,930**	
	Sig. (2-tailed)	,000	
	N	62	
Thinking Memory	Pearson Correlation	,750**	
	Sig. (2-tailed)	,000	
	N	62	
Attention	Pearson Correlation	,817**	
	Sig. (2-tailed)	,000	
	N	62	

Note: Own elaboration.

Based on the results obtained, the null hypothesis was rejected in favor of the alternative hypotheses, which establish significant relationships between the

perception of academic performance and metacognition in students of the Social Sciences Department at the Higher Pedagogical Institute in Puno.

DISCUSSION

The study conducted with students of the Social Sciences Department at the Higher Pedagogical Institute in Puno, found a favorable perception of academic performance in which 61.3% of participants indicated that they were "almost always" satisfied with their performance. This behavior is reflected in each of the analyzed dimensions of this variable, especially in the procedural (54.8% "almost always") and autonomous (61.3% "almost always") areas. However, the study identified opportunities to improve motivation and social interaction among students, as well as to encourage greater use of effective study and collaboration strategies, which could enhance their academic performance.

When comparing these results with other research that has measured similar variables, specifically considering academic performance, equally positive findings are observed. For example, Pineda et al. (2024) reported that student learning achievement was mostly acceptable in 67.4% of the students who participated in their study. Likewise, Martínez and Valencia (2021) found that 41.5% of students obtained between 16 and 18 points on a scale of 20, while 50.9% scored between 14 and 16 points, with none failing. Furthermore, Real et al. (2024), when investigating the factors associated with the perception of academic performance in university students in Latin America, in which students from Paraguay, Peru, Chile, and Cuba participated, revealed that 38.8% perceived good academic performance. These authors also found a significant correlation between poor academic performance and family dysfunction ($p < 0.001$), which highlights the importance of considering contextual factors when assessing academic performance.

The perception of Social Sciences students at the Higher Pedagogical Institute in Puno regarding their metacognitive skills is predominantly positive with 61.3% reporting feeling "almost always" competent in this area. This pattern is reflected in the dimensions analyzed, particularly in memory (54.8% "almost always") and comprehension (59.7% "almost always"). However, there are opportunities for improvement in the areas of attention (40.3% "sometimes") and critical thinking (25.8% "sometimes"), in which a significant proportion of students reported difficulties or variability in the use of these skills. In comparing this result with the study conducted in Peru by Benique and Cruz (2022), which included students from the Néstor Cáceres Velásquez Andean University and the National University of the Altiplano in Puno, it is observed that a high percentage (77.8%) of students agree with their metacognitive process. The authors consider it essential to continue promoting positive attitudes in students toward their own metacognitive processes,

as this has a favorable impact on their scientific attitudes and academic performance, as evidenced by the fact that more than 92% of them pass their courses. It is also recognized that there is a significant influence that professors and university institutions have on these results.

In line with this perspective, Garcés (2024) carried out an intervention program aimed at strengthening critical thinking skills and the use of metacognitive strategies in Peruvian university students. This program had a positive impact, with a significant improvement in the students' cognitive development. The author highlighted the importance of students acquiring these skills for their academic and professional success.

The study established significant relationships ($r = 0.994$ and $p = 0.000$) between perceived academic performance and metacognition in students of the Social Sciences program at the Higher Pedagogical Institute in Puno. It is possible to state that students develop metacognitive skills, such as awareness of their own learning, thinking, and problem-solving processes; thus, their academic performance tends to improve significantly. Furthermore, a substantial positive association was identified between academic performance and the following metacognitive dimensions: memory ($Rho = 0.930$), attention ($Rho = 0.930$), comprehension ($Rho = 0.750$), and thinking ($Rho = 0.817$), with $p = 0.000$ in all cases.

In comparing this finding with studies conducted in Peru by Pineda et al. (2024) and Escudero and Oseda (2021), the study reveals similar results. The first study was conducted with incoming Dentistry students at the National University of the Altiplano in Puno who applied the Pearson's chi-square, yielding a value of 33.764 and a p-value of 0.000, constituting a statistically significant relationship between metacognitive skills and learning achievement. The second study, conducted with students at an educational institution in Trujillo, also found a correlation between these variables, evidenced by the results obtained through Pearson's correlation coefficient ($r = 0.804$ and $p < 0.005$). Thus, the authors conclude that students' use of metacognitive strategies has a positive impact on their academic achievement.

Likewise, other Peruvian authors, Romero et al. (2022), found a positive perception of the use of graphical-schematic techniques as a metacognitive strategy, which significantly influences academic performance. The authors established a close and positive relationship between the variables by obtaining a Pearson correlation ($r = 0.956$ and $p = 0.000$) in a study conducted with students in the Faculty of Education at the Universidad Católica Sedes Sapientiae. Arias and Aparicio (2020) analyzed differences in metacognitive awareness and its dimensions at the beginning and end of the academic semester in first-year students of engineering, architecture, and aeronautical sciences programs at a private

university in Lima. As a result, they observed a significant and favorable change, although they were unable to establish significant relationships with gender or academic performance.

Similarly, studies conducted in other countries have also found consistent results. Martínez and Valencia (in 2021) established a moderately significant relationship ($r = 0.561$) between metacognitive strategies and academic performance in students from the Faculty of Chemical Sciences at the Escuela Superior Politécnica de Chimborazo in Ecuador. In another study, Betancourt (2020) analyzed students in the Executive Secretariat program at the Ismael Pérez Pazmiño Higher Technological Institute in Machala, Ecuador, and obtained a Pearson correlation coefficient of 0.846, leading to the conclusion that as learning strategies are applied, academic performance improves in the sample studied.

In contrast, Puma et al. (2020) did not establish a significant relationship between academic performance and metacognitive strategies among students at the Professional School of Education at the National Amazonian University of Madre de Dios, Peru. The Pearson correlation coefficient obtained was 0.333, indicating a weak relationship between these two variables. As a result, the authors concluded that there is no substantial correlation between academic performance and metacognitive strategies in the sample of students who participated in their research. Additionally, supporting the findings of this research and in line with studies that present similar conclusions, is the bibliographic review conducted by Cancino (2024). In her work, the author describes the influence of metacognitive strategies on the learning of university students in Latin America over the last ten years. She notes that, in the studies analyzed, there is a positive influence of metacognition in relation to learning, which indicates that these strategies are essential for achieving successful academic performance.

CONCLUSIONS

Based on the results of this research, it was determined that there is a significant relationship between perceived academic performance and metacognition among students in the Social Sciences program at the Higher Pedagogical Institute in Puno. This is supported by Spearman's Rho correlation coefficient, which was 0.994 ($p = 0.000$), suggesting that as students develop metacognitive skills, their academic performance tends to improve. Furthermore, a significant positive association was established between academic performance and the following metacognitive dimensions: memory ($Rho = 0.930$), attention ($Rho = 0.930$), comprehension ($Rho = 0.750$), and thinking ($Rho = 0.817$), with $p = 0.000$ in all cases. In this context, alternative hypotheses H1, H2, H3, H4, and H5 were accepted, and the null hypothesis H0 was rejected. Likewise, 61.3% of students reported feeling "almost

always" satisfied with their academic performance, a figure echoed in their perception of metacognition, indicating a positive perception of both variables. Regarding academic performance, the procedural (54.8% "almost always") and autonomous (61.3% "almost always") dimensions stood out. Regarding the dimensions of metacognition, memory (54.8% "almost always") and comprehension (59.7% "almost always") stood out.

These results underscore the need to foster the development of metacognitive skills as an essential element for improving academic performance. It is crucial to implement strategies that strengthen self-reflection and self-regulation in learning, as strengthening them will contribute to better academic performance and prepare students to face future challenges in their professional and personal lives. Therefore, integrating metacognition training into the educational curriculum should be considered a key strategy for promoting effective and sustainable learning.

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EMPLOYABILITY COMPETENCIES AND THE TEACHING PROCESS IN TECHNICAL AND PRODUCTIVE EDUCATION CENTERS

Segovia Aranibar, Senayda

ABSTRACT

In the current educational context, Technical Productive Education Centers play an important role in the training of students, oriented towards labor market insertion. However, there is concern that the competencies acquired by students may not always align with the labor market demands, which could limit their employability. The objective of this research was to establish the relationship between employability competencies and the teaching process in technical and productive education centers. The research methodology was quantitative, was basic in type, with a non-experimental design and a correlational scope. The population consisted of 1935 students, from which a sample of 221 was selected using stratified probabilistic sampling. For data collection, surveys and questionnaires were used as instruments to measure both variables. Hypothesis analysis was carried out through inferential statistics, using non-parametric Spearman's Rho test, in addition to descriptive statistics for the presentation and analysis of the results. The results obtained reveal that, regarding employability competencies, 59.2% of students perceive them as being at a good level. On the other hand, regarding the teaching process, 49.8% of students perceive it as being in progress with respect to the training provided by their teachers. It is concluded that there is a moderate positive relationship between employability competencies and the teaching process in Technical Productive Education Centers. In other words, an improvement in the educational process contributes to strengthening students' job competencies, although in a moderate manner.

Keywords: Cognitive competencies, digital competencies, employability competencies, teaching process.

INTRODUCTION

Technical and professional training is a fundamental pillar in the economic and social development of a country because it provides students with the necessary

skills to successfully enter the labor market. In particular, the Technical Productive Education Centers (CETPRO) play a key role in preparing young people to face the challenges of the working world. However, despite their importance, challenges persist in adapting the educational programs offered at these centers to meet the changing demands of the labor market. Employability competencies, which include both technical and socio-emotional skills, are essential for graduates to effectively integrate into the workforce.

The teaching process in CETPRO is a determining factor in the development of these competencies. However, there is concern that the pedagogical methods, teaching strategies, and the resources used are not always enough to ensure comprehensive training that responds to the labor market needs. In this context, it is essential to analyze the relationship between employability competencies and the teaching process in these centers in order to identify areas for improvement and contribute to the optimization of educational processes that strengthen students' employability.

Competency

According to Rios (2023), competency is a skill that employs different cognitive resources to address a specific type of situation. It involves the ability to transfer what has been learned, to learn independently, and to solve problems. Furthermore, in competency, the instructional process is based on constructive growth, rather than on mere accumulation of knowledge. Additionally, from a semantic point of view, competency is a concept linked both to work (the tasks in which a person must be competent) and to the individual. This last is manifested through a set of observable behaviors that lead to exceptional performance (Berrocal et al., 2021).

Employability

This refers to a person's ability to find employment, considering the interaction between their individual traits and the labor market (Paredes & Salas, 2020). Likewise, Gómez (2012) states that employability is understood in a very broad way; depending on how it is approached, which will determine the relationship between the employee and the employer. On the other hand, specialists point out that it is necessary to have motivation, emotional intelligence, and the ability to learn new technologies and work methods in order to be employable. Therefore, if you are looking for a job, it is essential to develop these skills along with management competencies and technical competencies to solve problems quickly. Anything else? Yes, in addition to this, you should add the skills the company requires and update your knowledge through continuing education. In addition, it is necessary to have a well-organized, updated, and adaptable résumé that speaks

for you. This is your letter of introduction, and since it is the first impression you offer to the company, you must review it before sending it (UPN, 2014).

Employability Competencies

According to Del Aguila et al. (2022), employability competencies are a group of skills or abilities that each individual possesses to attract employees to the job market, enabling them to perform well and meet their personal and company needs. Therefore, nowadays small, medium and large companies carefully examine the profile of management professionals in order to find the necessary skills to perform a specific job position. In that regard, selecting the appropriate personnel is fundamental to achieve organizational objectives and implement strategies, in order to achieve a distinctive brand.

Theories on Employability

- **Max Weber's Theory:** The term "*employability*" was introduced by Max Weber, a sociologist who, at the end of the 19th century, attempted to determine the qualities of employees for personnel selection in companies through a survey. The term "*employability of workers*" began to be used as a result of his research. The tendency for employees to demonstrate their abilities and skills persisted until the world was transformed the labor perspective, which became one of labor subjugation for prisoners. In the post-war period, this trend intensified (Meza, 2017).
- **Kathleen Cotton's Theory:** This author conducted a study focused on employers' requirements and determined that market demands include attitudes, basic competencies, and a willingness to work as part of a team. She also classified three types of demand: affective skills (which are the most important), thinking skills, and basic skills (Lopez, 2021).
- **Human Capital Theory:** This theory was initiated by Theodore. In his 1961 work titled, "*Education and Economic Growth*", which is based on the Solow's growth model, he argues that education is an investment made by individuals because it enables them to improve their competencies and obtain more advanced human capital, which becomes a key factor for economic growth. This is because, at a personal level, it allows individuals to improve their economic and social situation and obtain access to more goods and services (Cardona, 2007, citado por Curo, 2024).

Teaching

Teaching is an interactive process aimed at promoting the complete development of students, not only to impart knowledge, but also to foster skills, values, and

attitudes that enable them to face life's challenges and contribute meaningfully to society (Trujillo, 2019). Therefore, from its projective dimension, which includes its design, implementation, evaluation, and the orientation of its results toward the personal and social aspects, the teaching-learning process must be studied and investigated. From a diagnosed present to a desirable future, it is important to consider the diversity of participants and the multilateral nature of the interrelationships (Rochina et al., 2020).

In this regard, Seijo et al. (2010) argue that the teaching-learning process includes personal and non-personal elements. These elements must be mastered by the teacher. The individuals involved, such as the teacher, the students, and the group, are among the personal elements and provide a communicative and interactive dimension to the process. Non-personal elements include methods, content, objectives, organizational structures, and evaluation. The educator must also master these components, making the best use of them and defining them precisely in order to achieve the students' holistic development according to the principle of education through instruction.

In this sense, if teaching is analyzed in its most genuine and current definition, it becomes clear that teaching specifically means anticipating and projecting the progress of this process, establishing a functional organization for the program, and gathering the bibliographic resources and the means required to study and illustrate the subject matter. This allows students to begin studying the subject, motivating them, providing them with the necessary information, guiding their reasoning, clarifying their doubts, and strengthening their progressive understanding and mastery of the content (De Jesús, 2024).

Theory on the Teaching-Learning Process

David Ausubel's Theory: Meaningful learning occurs through significant, non-arbitrary connections. In other words, this type of learning requires meaning when the individual incorporates new knowledge into their cognitive structure and establishes the necessary connections with prior knowledge. Ausubel compares discovery learning with expository learning in the assimilation theory, since the latter can be equivalent and effective under certain circumstances. This is fundamental to acquiring new meaning, because it requires meaningful attitudes toward learning and a significant commitment to the individuals involved (Anicama & Lopez, 2025).

Therefore, promoting research in order to encourage educational practices simply means restoring or recovering the natural link between human beings and their socio-natural contexts; that is, returning to the concrete essence of the individual, which is comprised of their origin, existence, and resonance in terms of

time, space, and their environment. Certainly, it is not easy to determine the exact origin of this pedagogical trend from the perspective of formal education, as it is recognized today (Mora, 2009).

A. Teaching Resources

Teaching resources are a collection of components that help carry out the teaching and learning process. These resources help students achieve specific knowledge by providing them with sensory experiences that represent that knowledge. They include any material used to make the development of educational activities easier within a specific educational context. In this regard, Vargas (2017) explains that the functions of teaching resources must consider the target audience for the resource to be truly useful. The functions of teaching resources include: a) providing information, b) achieving an objective, c) guiding the teaching and learning process, d) placing students within a context, e) facilitating communication between teachers and students, f) bringing ideas closer to the senses, and g) motivating students.

In short, teaching resources are the means and materials applied or used in the learning process, ranging from traditional to new technological media. In addition, teaching resources do not have value in themselves; their use is fully justified only when they are appropriately incorporated into the educational process, which must also be compatible with broader contexts.

B. Teaching Strategies

Teaching and learning strategies are techniques or tools (knowledge organizers) used by the teacher with the aim of promoting meaningful learning, which in turn can be implemented based on the procedures contained in cognitive strategies (cognitive skills). This is based on the key premise that the teacher (the learning facilitator), in addition to teaching the topics related to their specialty, assumes the responsibility of teaching students how to learn (Mendoza & Mamani, 2012). Likewise, Garcia et al. (2025) state that teaching strategies are techniques or procedures used by teachers in order to ensure that their students achieve meaningful learning.

This dimension is understood as the methods and resources that the educator uses in the teaching and learning process, contextualizing them according to the students' needs, generating active participation, and developing critical thinking. On the other hand, the teaching strategies can vary according to the students' needs, with the purpose of achieving the academic objectives.

C. Teaching Activities

Learning activities are tools or practices used throughout an educational process in order to promote understanding and facilitate the assimilation of new concepts. These activities motivate students to participate actively in a learning program and, although their nature may vary, the fundamental aspect is that they are strategically designed to achieve learning goals (Zambrano et al., 2022). For this reason, choosing activities that stimulate students' responses and participation is an essential component of the teaching and learning process. Students will be more willing to assimilate and put into practice the concepts, ideas, and topics presented in the classroom once they participate in the teaching and learning process through creative activities.

Finally, this dimension is understood as the actions directed toward facilitating and achieving active learning. In addition, learning activities promote proper understanding and meaningful learning; this also involves learning strategies and didactic resources with the purpose of achieving the proposed objective.

METHOD

The target population for this research is located in the city of Puno, and is composed of 1935 students and 69 teachers distributed across 4 state-managed Technical-Productive Education Centers (CETPROs).

For this research, the quantitative approach was used. In this process, information is collected to verify assumptions through quantification and statistical study, with the purpose of providing guidelines about behavioral patterns and validating theories (Hernández et al., 2014).

This research corresponds to basic research, and its design is non-experimental. This type of design is characterized by the observation of variables as they occur in their natural environment, without the researcher manipulating any of them. According to Charaja (2018), non-experimental designs are useful when the aim is to study phenomena in their natural context, allowing valid information to be obtained without the direct influence of the researcher.

The level of research is correlational, since the purpose is to establish and measure the relationship between two or more variables. In a correlational study, the objective is to identify whether an association or link exists between the variables without intervening in or modifying the environmental conditions. This type of research allows the researcher to understand the nature and magnitude of the relationship between the variables (Charaja, 2018).

RESULTS

Result of the overall objective

Table 1

Relationship between employability competencies and the teaching process in technical and productive education center.

		Teaching process				Total
		Deficient	In progress	Enough	Outstanding	
<i>Employability competencies</i>	Deficient	f	4	0	0	4
		%	1,2%	0,0%	0,0%	1,2%
	Regular	f	14	44	7	66
		%	4,4%	13,7%	2,2%	20,6%
	Good	f	3	108	77	190
		%	0,9%	33,6%	24,0%	59,2%
	Very good	f	0	8	46	61
		%	0,0%	2,5%	14,3%	19,0%
	Total	f	21	160	130	321
		%	6,5%	49,8%	40,5%	100,0%

Note. Database

Overall, the results indicate that the teaching process in CETPROs is mostly located at the "in progress" (49.8%) and "sufficient" (40.5%) levels, which suggest that students' perception of educational quality is generally positive, although it does not reach outstanding levels. The deficient (6.5%) and outstanding (3.1%) levels are significantly lower, reflecting that, although the teaching process is perceived adequate by most students, there are still key aspects that need improvement.

The results of the analysis suggest a positive relationship between students' Competencies for employability and the teaching process at CETPROs (Centers for Technical and Productive Education). Students with higher competencies tend to perceive the teaching process at a more favorable level.

Table 2

General Hypothesis Test

		Employability competencies	Teaching process
Spearman's Rho	Employability competencies	Correlation coefficient	1,000
		Sig. (bilateral)	,538**
		N	,000
	Teaching process	Correlation coefficient	321
		Sig. (bilateral)	,538**
		N	,000

Ho: There is no relationship between employability competencies and the teaching process in technical and productive education centers.

Ha: There is a relationship between employability competencies and the teaching process in technical and productive education centers.

Table 2 presents the results of the general hypothesis test conducted to determine the relationship between employability competencies and the teaching process in technical and productive education centers. For this test, Spearman's Rho coefficient was used, which measures the strength and direction of the relationship between both variables.

The correlation coefficient obtained is 0.538, which, according to Spearman's Rho scale presented in Table 4, indicates a moderate positive correlation. In practical terms, this result suggests that as the quality of the teaching process increases, students' employability competencies also tend to improve.

Result of Specific Objective 1

Table 3

Relationship between technical employability competencies and the teaching process in technical and productive education centers.

		Teaching process				Total	
		Deficient	In process	Enough	Outstanding		
Technical Competencies	Deficient	f	10	8	0	0	18
		%	3,1%	2,5%	0,0%	0,0%	5,6%
	Regular	f	7	66	37	0	110
		%	2,2%	20,6%	11,5%	0,0%	34,3%
	Good	f	4	72	41	1	118
		%	1,2%	22,4%	12,8%	0,3%	36,8%
	Very good	f	0	14	52	9	75
		%	0,0%	4,4%	16,2%	2,8%	23,4%
Total	f	21	160	130	10	321	
	%	6,5%	49,8%	40,5%	3,1%	100,0%	

Note. Database

The results of the analysis suggest that there is a positive relationship between technical employability competencies and the teaching process in CETPROs, based on students' perspectives. As the teaching process is rated as sufficient or outstanding, the proportion of students with good and very good technical competencies increases. However, the predominance of the “in progress” level highlights the need to strengthen pedagogical strategies, practical training, and technological updates in order to improve students' technical preparation and promote more a more competitive and effective labor market insertion.

Table 4

Specific Hypothesis Test 1

		Technical Competencies	Teaching process
Spearman's Rho	Technical Competencies	Correlation coefficient	1,000
		Sig. (bilateral)	,000
		N	321
	Teaching process	Correlation coefficient	,444**
		Sig. (bilateral)	,000
		N	321

Ho: There is no relationship between technical employability competencies and the teaching process in technical and productive education centers.

Ha: There is a relationship between technical employability competencies and the teaching process in technical and productive education centers.

Table 4 shows the results of specific hypothesis test 1 conducted to determine the relationship between technical employability competencies and the teaching process in technical and productive education centers. For this test, the Spearman's Rho coefficient was used, which measures the intensity and direction of the relationship between the two variables.

The correlation coefficient obtained is 0.444, which, according to Spearman's Rho rating scale presented in Table 4, indicates a moderate positive correlation. In practical terms, this result suggests that as the teaching process in CETPROs improves, students' technical skills also tend to improve. In other words, the educational process has a positive and moderate impact on the development of students' technical employability competencies. However, the relationship is not particularly strong, suggesting that other factors may also influence the development of these competencies.

CONCLUSIONS

There is a moderate positive relationship between employability competencies and the teaching process in technical and productive education centers. The correlation coefficient is 0.538, with a bilateral significance of 0.000, which is less than 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected.

There is a moderate positive relationship between technical employability competencies and the teaching process in technical and productive education centers. The correlation coefficient is 0.444, with a bilateral significance of 0.000, which is less than 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected.

There is a low positive correlation between cognitive employability competencies and the teaching process in technical and productive education centers. The correlation coefficient is 0.345, with a bilateral significance of 0.000, which is less than 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected.

There is a moderate positive relationship between socio-personal employability competencies and the teaching process in technical and production education centers. The correlation coefficient is 0.450, with a bilateral significance of 0.000,

which is less than 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected.

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Engineering



IMPLEMENTATION OF A MOBILE APPLICATION TO MONITOR VEHICLES OF INTERPROVINCIAL TRANSPORT COMPANIES IN THE REGIONAL DIRECTORATE OF TRANSPORT AND COMMUNICATIONS PUNO

Apaza Quispe, Yeni Mezulan

ABSTRACT

Interprovincial passenger transportation constitutes a fundamental activity for the economic and social development of regions, as it allows the mobility of people between different locations and contributes to the dynamism of commercial, educational, and productive activities. In this context, the institutions responsible for the supervision and regulation of land transportation play an essential role in ensuring that transport companies comply with the regulations established by current legislation and provide safe and adequate services to users. At the Regional Directorate of Transport and Communications of Puno (DRTC Puno), the vehicle inspection process is carried out through control operations conducted by transport inspectors, who verify the documentation of the driver, the vehicle, and the transport company. However, this process is mainly carried out manually, which generates several difficulties during field inspections, such as errors in information recording, delays in completing inspection reports, and difficulties in accessing the necessary data to perform the required verification. Given this problem, the objective of this study was to implement a mobile application to improve the inspection process of authorized vehicles from interprovincial transport companies at the Regional Directorate of Transport and Communications of Puno. The research is applied in nature with a quasi-experimental design, in which the results of the inspection process were evaluated before and after the implementation of the system. The Mobile-D agile methodology was used for the development of the application, allowing the system to be designed and built iteratively according to user needs. The results show a significant reduction in the average inspection time, decreasing from 13.10 minutes to 7.40 minutes per intervention. Additionally, a considerable decrease in errors associated with the completion of inspection reports was observed. The system evaluation indicated that 90% of users consider that the application meets the established quality requirements. It is concluded that the implementation of a mobile application significantly contributes to improving the vehicle inspection process by optimizing intervention time and reducing errors in

information recording, thereby improving the operational efficiency of the institution responsible for supervising interprovincial transportation.

Keywords: mobile application, vehicle inspection, interprovincial transport, information systems, Mobile-D.

INTRODUCTION

In recent years, the advancement of information technologies has enabled the development of various technological solutions aimed at improving process management in both public and private organizations. In this context, mobile applications have become an important technological tool for optimizing operational activities that require information recording in field environments. According to Aguilar and Aguilar (2023), the use of mobile applications improves information management and reduces response times in administrative processes related to traffic violation control.

Furthermore, several studies have shown that the implementation of mobile applications can significantly improve supervision and control processes in the transportation sector. Altamirano (2018) developed a mobile application for managing georeferenced traffic violations aimed at municipal inspectors, demonstrating improvements in information recording during inspection interventions. Similarly, Chuquija (2019) developed a mobile application with geolocation features aimed at controlling and managing driver safety, demonstrating that the use of mobile technologies facilitates the monitoring of transportation-related activities and improves operational management.

On the other hand, studies related to the development of technological systems for transportation management have also demonstrated important benefits in optimizing administrative processes. Anccas (2020) proposed a technological model based on web applications to optimize process management related to the transportation of minor vehicles, highlighting that the digitalization of procedures improves information control and strengthens institutional management.

Likewise, research related to vehicle monitoring and control through digital systems has shown significant improvements in the operational efficiency of organizations. Ticona (2021) developed a vehicle monitoring system using GPS technology that improved vehicle management in a transportation company, demonstrating that the use of technological tools facilitates the monitoring of vehicle units and improves decision-making processes. In the same sense, Velásquez and Luque (2021) demonstrated that the implementation of monitoring systems through mobile devices improves transportation unit control and optimizes access to operational information.

Additionally, recent research related to the development of mobile applications for managing georeferenced information has shown benefits in public management. Ibarra and Rivera (2024) developed a mobile application with geolocation capabilities for citizen reporting of damage to urban infrastructure, concluding that mobile technologies improve field data collection and optimize data management processes.

Complementary studies related to the use of mobile applications for vehicle monitoring have shown that these technological tools contribute to improving the control and tracking of vehicle units during their operations. Quispe (2022) developed a system based on mobile applications and geofencing to improve vehicle monitoring during the transportation of liquefied petroleum gas, demonstrating that the use of digital technologies reduces operational risks and improves vehicle control indicators.

In the Peruvian context, the Superintendency of Land Transport of People, Cargo and Goods has implemented technological tools aimed at improving land transportation inspection processes, such as the Fiscamóvil platform, which allows inspectors to record information during control operations using mobile devices. These initiatives demonstrate the importance of incorporating technological solutions into transportation supervision processes to improve the efficiency of inspection activities.

METHODS

This research is applied in nature, as its purpose is to develop and implement a technological solution aimed at improving the inspection process of interprovincial transport vehicles at the Regional Directorate of Transport and Communications of Puno. Applied research seeks to solve a specific problem through the application of technological and methodological knowledge in a real context.

The research design is quasi-experimental, since a comparison was conducted between the inspection process before and after the implementation of the mobile application. This approach made it possible to evaluate the impact of the technological tool on variables such as the average inspection time and the reduction of errors in the completion of inspection reports.

The study population consisted of transport inspectors from the Regional Directorate of Transport and Communications of Puno who participate in vehicle inspection operations. These inspectors perform interventions at different control points where they verify documentation related to drivers, vehicles, and transport companies.

Data collection was carried out using inspection records generated during control operations. The average time required to perform each inspection was measured, and errors detected in the completion of inspection reports were analyzed. These data were compared before and after the implementation of the mobile application to evaluate its impact on process improvement.

For the development of the mobile application, an agile methodology oriented to mobile software development was used. This methodology allowed structuring the system development process into different phases, including requirement analysis, system design, application development, and system testing, enabling the creation of a technological tool adapted to the operational needs of transport inspectors.

RESULTS

Comparison of Inspection Time

One of the most important indicators evaluated was the average time required to perform the vehicle inspection process before and after the implementation of the mobile application. This indicator allows analyzing the impact of the system on the efficiency of the inspectors' work.

Before the implementation of the application, the inspection process was carried out manually, which involved reviewing physical documents, recording information in printed forms, and later processing the data in the institution's administrative systems. This methodology generated delays during field interventions.

With the implementation of the mobile application, information is recorded digitally, allowing the inspection report to be completed directly from the mobile device.

Table 1

Average time of the inspection process

Scenario	Average time (minutes)
Before application	13.10
After application	7.40

Note. The results show a significant reduction in inspection time, improving the operational efficiency of inspectors.

Reduction of Errors in Inspection Reports

Another aspect evaluated in the research was the number of errors detected in the information recorded in inspection reports. Before the implementation of the mobile application, inspectors manually recorded driver, vehicle, and violation information, which generated errors in data recording.

With the implementation of the mobile application, the system automatically validated certain fields and structured the information, reducing the probability of errors during the inspection process.

Table 2

Errors in inspection reports

Record Type	Before system	After system
Driver data	8	2
Vehicle data	6	1
Violation records	5	1
Total errors	19	4

Note. The results show a significant decrease in errors recorded during the auditing process, which improves the reliability of the information collected during the control operations.

System Quality Evaluation

To evaluate the quality of the developed application, the ISO 9126 standard was used, which considers different attributes related to software performance.

A survey was conducted among inspectors who used the application during inspection operations.

Table 3

System quality evaluation

Criterion	Acceptance level
Functionality	92%
Usability	88%
Efficiency	91%
Reliability	89%
Overall average	90%

Note. The results indicate that the system has a high level of user acceptance, demonstrating that the application meets the necessary requirements for use during inspection operations.

DISCUSSION

The results obtained in this research demonstrate that the implementation of a mobile application significantly contributes to improving the inspection process for interprovincial transport vehicles at the Puno Regional Directorate of Transportation and Communications. Specifically, a significant reduction was observed in the average time required to carry out inspections, as well as a considerable decrease in errors associated with recording information in the inspection reports.

The results obtained in this research are also related to several studies that analyze the use of mobile technologies to improve the management of transportation-related processes. For example, Apaza and Ramos (2017) demonstrated that the implementation of mobile applications can optimize administrative processes by automating information recording and digitizing operational procedures. These findings reinforce the importance of incorporating technological tools in public institutions, as they improve process efficiency and reduce errors associated with manual procedures.

Regarding inspection time, the results show that the average intervention time decreased from 13.10 minutes to 7.40 minutes after the implementation of the mobile application. This improvement is mainly due to the automation of information recording and the ease of entering data in a structured manner through the developed system. These results coincide with those reported by Aguilar and Aguilar (2023), who indicate that the implementation of mobile applications for managing traffic violations optimizes information recording processes and reduces response times in operational enforcement activities.

Similarly, Altamirano (2018) developed a mobile application for managing georeferenced traffic violations for municipal inspectors, finding that the use of technological tools improves the efficiency of data recording during enforcement processes. This study highlights that digitizing control procedures facilitates the inspectors' work by reducing the manual tasks associated with filling out physical documents.

Another relevant finding of this research was the reduction in errors in data entry during the audit process. Before the implementation of the mobile application, 19 errors were recorded in the audit reports, while after using the system, the number of errors was reduced to 4. This improvement is mainly due to the application's ability to automatically validate certain data fields, thus decreasing the likelihood of errors during data entry.

These results are consistent with those reported by Rosas (2023), who points out that the use of mobile technologies in transportation oversight processes improves the accuracy of records and the reliability of information collected during interventions. Furthermore, the author highlights that the digitization of oversight processes contributes to improving the administrative management of the entities responsible for transportation control.

On the other hand, studies related to vehicle monitoring and control using mobile systems have also shown similar benefits in terms of operational efficiency and information management. Ticona (2021) developed a GPS-based vehicle monitoring system to improve vehicle management in a transportation company, finding that the use of digital technologies optimizes vehicle tracking and improves decision-making in control processes.

Additionally, Velásquez and Luque (2021) demonstrated that implementing mobile systems for monitoring transport units improves operational control and facilitates access to information related to vehicle location and status. These results reinforce the importance of using technological tools in transport management, especially in activities that require constant supervision and control.

Similarly, in the Peruvian context, the Superintendency of Land Transportation of Passengers, Cargo, and Goods has developed technological tools aimed at improving land transportation oversight processes, such as the Fiscamóvil platform, which allows inspectors to record information during operations using mobile devices. This type of initiative demonstrates that the incorporation of digital technologies into oversight processes is a growing trend among the entities responsible for supervising transportation.

In this sense, the results obtained in this research confirm that the implementation of mobile applications can significantly contribute to improving the efficiency of vehicle inspection processes, allowing for optimized intervention times, reduced errors in information recording, and improved management of data obtained during control operations.

Finally, the system evaluation results show a high level of user acceptance, with users finding the mobile application easier to perform during inspection operations. This demonstrates that the developed system adequately meets the operational needs of transport inspectors and represents a useful technological tool for improving the interprovincial transport oversight process.

CONCLUSION

The implementation of a mobile application for the inspection of interprovincial transport vehicles significantly improved the control process carried out by inspectors from the Puno Regional Directorate of Transportation and Communications. The results obtained demonstrate that the use of technological tools contributes to optimizing operational activities related to the supervision of land transport.

In particular, a considerable reduction was observed in the average time required to carry out inspections, decreasing from 13.10 minutes to 7.40 minutes per inspection. This demonstrates that automating information recording streamlines the inspectors' work during control operations.

Likewise, a significant decrease in errors associated with completing inspection reports was observed, which contributes to improving the reliability and accuracy of the information recorded during the inspections. This result demonstrates that the use of digital systems allows for the proper structuring of data and reduces inconsistencies generated during manual recording processes.

On the other hand, the system evaluation showed a high level of user acceptance, with users finding that the mobile application facilitates their work and improves the efficiency of the vehicle inspection process.

Consequently, the implementation of mobile applications represents a viable technological alternative for modernizing the supervision and control processes of land transportation in public entities, contributing to improved institutional management, optimized intervention times, and strengthened oversight mechanisms for interprovincial transportation services.

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SERVICE ROBOTS, ROS 2, AND EMBEDDED PLATFORMS: A TECHNICAL SYNTHESIS FOR SERVICE ROBOTICS

Aquise Pari, John Hubert

ABSTRACT

Service robotics has accelerated its adoption in logistics, healthcare, and professional cleaning, driven by operational demands and scalable deployment models such as Robot-as-a-Service (RaaS) (International Federation of Robotics [IFR], 2025; Polaris Market Research, 2024). In software, ROS 2 emerges as a reference infrastructure for distributed production systems by incorporating DDS, Quality of Service (QoS) policies, and a security framework aligned with DDS-Security (Macenski et al., 2022; Maruyama et al., 2016; Robotnik Automation, 2024). In hardware, the choice between Raspberry Pi and NVIDIA Jetson Nano defines the practical boundary between efficient control/IO and GPU-accelerated AI perception (NVIDIA Corporation, 2019; Raspberry Pi Foundation, 2023; ThinkRobotics, 2024). This review synthesizes market trends, technical foundations of ROS 2, and decision criteria for embedded platforms, proposing reference architectures for service robots.

Keywords: service robots, ROS 2, DDS, QoS, Raspberry Pi, Jetson Nano, edge AI, embedded robotics.

INTRODUCTION

This review article aims to synthesize design criteria for service robots based on ROS 2 and embedded computing. To facilitate traceability, Section 1 establishes the market context and motivation supported by Table 1; Section 2 summarizes ROS 2 architectural decisions and contrasts key contributions from the literature in Table 2; Section 3 compares embedded platforms with emphasis on AI workloads (Table 3); and Section 4 proposes a task–stack–platform mapping for integration with ROS 2 (Table 4). Finally, conclusions oriented toward reproducible and measurable deployments are presented.

In software, the transition toward ROS 2 responds to typical production requirements: DDS-based distributed communication, per-flow QoS configuration, and security mechanisms aligned with DDS (Macenski et al., 2022; Maruyama et al., 2016; Robotnik Automation, 2024). In hardware, the choice of embedded platform determines latency, power consumption, and perception capability: Raspberry Pi is competitive for control and integration, while Jetson Nano enables GPU-accelerated inference in computer vision and deep learning (NVIDIA Corporation, 2019; Raspberry Pi Foundation, 2023; ThinkRobotics, 2024).

Service robotics is currently undergoing a consolidation phase driven by process automation and fleet deployment in real-world environments, especially in logistics, professional cleaning, and healthcare (International Federation of Robotics [IFR], 2025). In parallel, the expansion of business models such as Robot-as-a-Service (RaaS) and projected market growth reinforce the need for architectures with remote maintenance, security, and scalability by design (Grand View Research, 2024; Polaris Market Research, 2024).

1. Context

Sector evidence indicates that service robotics is transitioning from isolated units to operational fleets, where scalability, remote maintenance, security, and traceability become design requirements (IFR, 2025; Polaris Market Research, 2024). In this context, Table 1 summarizes observed growth drivers and their direct engineering implications: systems must maintain performance and reliability under imperfect networks, workload variations, and long-term deployments (IFR, 2025).

Table 1

Market trends and their technical implications (2024–2025)

Axis	Reported Evidence	Engineering Implication
Commercial growth and expansion	Sustained increase in professional service robots (IFR, 2025)	Requires observability, updates, and maintenance at scale (IFR, 2025)
Logistics/transport dominance	High participation of this segment in sales (IFR, 2025)	Emphasizes robust navigation, operational safety, and fleet management (IFR, 2025)
Expansion of RaaS	Growth of subscription-based models (IFR, 2025)	Requires telemetry, resilience, and cybersecurity by default (IFR, 2025; Polaris Market Research, 2024)
Projections to 2030	Expanding market (Grand View Research, 2024)	Favors reusable platforms: ROS 2 + modular embedded computing (Macenski et al., 2022; Grand View Research, 2024)

2. ROS 2: Architectural Decisions for Production

ROS 1 consolidated an ecosystem for prototyping; however, structural limitations associated with network assumptions, security, and scalability motivated the design of ROS 2 as a foundation for distributed production systems (Macenski et al., 2022; Robotnik Automation, 2024).

From an engineering perspective, ROS 2 relies on DDS for discovery and communication, incorporates QoS policies per data flow, and enables integrated security mechanisms through DDS-Security (Maruyama et al., 2016; Macenski et al., 2022). Table 2 consolidates evidence by author and its specific technical contribution, useful for justifying design and evaluation decisions.

Table 2

Author comparison: technical contributions on ROS 2

Topic	Technical Finding	Source
Design and production use	ROS 2 as an architecture oriented toward real-world deployments.	Macenski et al. (2022)
DDS + QoS	Performance evaluation and QoS implications in ROS 2.	Maruyama et al. (2016)
Temporal characteristics in multi-agent systems	Empirical evidence on temporal behavior in multi-robot systems.	Park et al. (2020)
Optimization and performance evaluation	Methods for optimization and performance measurement in real-time ROS 2 scenarios.	Ye et al. (2023)
Industrial orientation and transition	Practical synthesis of industrial motivations and key ROS 2 points.	Robotnik Automation (2024)
Official documentation	Documentation and ecosystem guidelines for ROS 2.	Open Robotics (2024)

3. Embedded Platforms: Raspberry Pi vs. Jetson Nano

In service robotics, the bottleneck tends to shift toward perception and inference: more sensors, cameras, and SLAM increase latency and throughput requirements. Consequently, the embedded platform defines the practical limits of performance and energy efficiency.

Table 3 presents a comparison oriented toward computational role selection, distinguishing general embedded computing and integration (Raspberry Pi) from GPU-accelerated inference (Jetson Nano) (Raspberry Pi Foundation, 2023; NVIDIA Corporation, 2019).

Table 3

Technical comparison for decision-making: Raspberry Pi and Jetson Nano

Criterion	Raspberry Pi (typical use)	Jetson Nano (typical use)	Source
Design orientation	General computing	Edge AI with CUDA GPU	Raspberry Pi Foundation (2023); NVIDIA Corporation (2019)
Main strength	Integration, flexibility	Accelerated inference (TensorRT/CUDA)	NVIDIA Corporation (2019); ThinkRobotics (2024)
Evidence in vision/AI	Lower performance without dedicated acceleration	Significant advantage due to GPU acceleration	Abdulhaq & Ahmed (2025); ThinkRobotics (2024)
Comparisons in applied vision	Observable differences depending on workload	Better performance in intensive workloads	Dewantoro et al. (2021)
Lifecycle considerations	Continuous evolution of the family	Developer Kit end-of-life; modules and alternatives	ThinkRobotics (2024)

4. ROS 2 + Hardware Integration: Architecture by Workload Partitioning

A recurring strategy in service robots is workload partitioning: control/IO and auxiliary sensing in a lightweight node, perception/AI in an accelerated node, and ROS 2 as the integration bus with QoS configured by criticality (Maruyama et al., 2016; Macenski et al., 2022).

Table 4 summarizes a practical mapping of tasks to ROS 2 stacks and suggested platforms, facilitating traceability between functional requirements, architectural decisions, and evaluation metrics (Open Robotics, 2024).

Table 4

Tarea a stack ROS 2 y plataforma sugerida

Tarea	Stack/nodos típicos	Plataforma sugerida	Fuente
Navigation and planning	Nav2 (planning/control)	Mixed (depending on sensors)	Macenski et al. (2022); Open Robotics (2024)
Vision and inference	Camera pipeline + inference (YOLO/ResNet)	Jetson Nano	NVIDIA Corporation (2019); Abdulhaq & Ahmed (2025); ThinkRobotics (2024)
Low-level control	Drivers, actuator control, GPIO	Raspberry Pi	Raspberry Pi Foundation (2023)
Critical communications	DDS + QoS per topic	Both	Maruyama et al. (2016); Macenski et al. (2022)
Temporal evaluation	Latency/jitter measurement + tuning	Both (system dependent)	Park et al. (2020); Ye et al. (2023)

CONCLUSIONS

Sector growth and the transition toward operational fleets raise the minimum product requirements: observability, remote maintenance, resilience, and cybersecurity must be integrated into the architecture from the design phase (IFR, 2025; Polaris Market Research, 2024). Market evidence (Table 1) suggests that these capabilities determine deployment viability, especially in logistics and RaaS schemes.

ROS 2 provides structural advantages aligned with production environments. The adoption of DDS and QoS configuration enables communication design based on criticality (control vs. telemetry) and reduces single points of failure in distributed systems (Maruyama et al., 2016; Macenski et al., 2022). Additionally, empirical and optimization studies report that temporal performance can improve through middleware configuration and tuning practices, although results depend on the operating system, workload, and runtime parameters (Park et al., 2020; Ye et al., 2023).

Hardware selection should be formulated as a workload decision: control/IO versus perception/AI. Raspberry Pi is competitive as a control and integration node due to cost and ecosystem, while Jetson Nano stands out when perception and inference dominate the computational budget because of its GPU and tools such as TensorRT (Raspberry Pi Foundation, 2023; NVIDIA Corporation, 2019; ThinkRobotics, 2024). Comparative evidence in embedded vision supports this role-based separation (Abdulhaq & Ahmed, 2025; Dewantoro et al., 2021).

Hybrid architectures improve maintainability and risk control by decoupling modules: they allow perception scaling without redesigning control, facilitate controlled degradation, and simplify A/B performance testing (Table 4) (Macenski et al., 2022; Open Robotics, 2024). From an experimental engineering perspective, these partitioning increases bottleneck traceability and strengthens the internal validity of comparisons.

Finally, for publishable contributions in IEEE-oriented research lines, the differentiator lies in decision–metric traceability: explicitly linking QoS policies, middleware, and platform with quantifiable indicators (end-to-end latency, jitter, power consumption, task success rate, collisions per meter, vision throughput). This approach connects design with empirical evidence, aligning with rigor criteria typical in robotic systems evaluation (Park et al., 2020; Ye et al., 2023; Maruyama et al., 2016).

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FACTORS LIMITING E-COMMERCE GROWTH IN THE PERUVIAN ALTIPLANO 2025

Choquetinco Mamani, Rene

ABSTRACT

This review article analyzes the factors that influence the development of e-commerce in the Puno region of Peru, with a special focus on the Puno-Juliaca trade corridor. Despite the rapid growth of digitalization nationwide, the Altiplano region exhibits a unique dynamic characterized by the predominance of social commerce and the persistence of structural barriers. Using a descriptive methodological approach and analyzing connectivity and consumer behavior data, three critical factors limiting its expansion are identified: systemic distrust in digital payment methods, deficiencies in the "last mile" logistics infrastructure due to the region's rugged geography, and high levels of informality in online sales processes. The results indicate that, while cities like Juliaca act as engines of mass exchange, the lack of technical digital literacy hinders the transition from subsistence commerce to scalable e-commerce models. It is concluded that implementing digital formalization policies and strengthening consumer confidence are imperative to harness the export potential of the region's artisanal and commercial sectors.

Keywords: E-commerce, Digital divide, Logistics.

INTRODUCTION

Over the last decade, e-commerce in Peru has experienced exponential growth, consolidating itself as a fundamental pillar of the national economy. According to reports from the Peruvian Chamber of Electronic Commerce (CAPECE), the 2020 pandemic acted as a catalyst, accelerating digital adoption in the country by five years. However, this progress has not been uniformed across all regions. While the capital concentrates the largest volume of formal transactions, regions with high commercial dynamism, such as Puno, present a particular phenomenon: accelerated but predominantly informal digitalization.

The Puno region, and specifically the city of Juliaca, is positioned as the most important commercial hub in the southern Andes and a strategic node for cross-border trade with Bolivia. The paradox in Puno lies in the fact that, although there is massive use of digital tools for sales—a phenomenon known as social commerce—levels of formality and digital security remain precarious.

Caceda (2024). E-commerce in the Provinces. Ecommerce Observatory, 2010. Systemic distrust in digital payment methods in the Puno region is a complex phenomenon that combines cultural, infrastructural, and security factors. Although the region has high commercial potential, various barriers limit the widespread adoption of non-face-to-face payments.

InveCom Journal (2025). Impact of e-commerce on SME competitiveness: Key factors and technological barriers. InveCom Journal: Transdisciplinary Studies in Communication and Society, 5(4), 1-8. Digital and Financial Literacy Gap: A large part of the population in Puno, especially in rural areas and among older micro-entrepreneurs, lacks the technical skills to securely manage banking applications. The fear of making a mistake in a transfer and "losing the money" is a constant psychological barrier.

InveCom Journal (2025). Impact of e-commerce on SME competitiveness: Key factors and technological barriers. InveCom Journal: Transdisciplinary Studies in Communication and Society, 5(4), 1-8. Rise of Cyber Scams and Perception of Insecurity. The increase in scams such as phishing (fake emails) and vishing (fraudulent calls) has strongly impacted regional perceptions. Since Puno is an area with high commercial activity (border trade and fairs), users prefer the "physical security" of cash.

Peruvian Chamber of Electronic Commerce [CAPECE]. (2025). Official Report on the Ecommerce Industry in Peru 2024-2025. The Cultural Value of "Cash in Hand" In the commercial culture of the Altiplano, the physical exchange of money is a symbol of closing a deal and mutual trust. There is a historical distrust of financial institutions, exacerbated by past crises, leading to a preference for the tangibility of banknotes over a digital balance.

Informality and Tax Evasion Puno registers one of the highest rates of informal employment and commerce in Peru (exceeding 80%-90% in certain sectors). Digital payment methods leave a "trace" that many merchants prefer to avoid in order to evade audits by SUNAT (the Peruvian tax authority).

National Institute of Statistics and Informatics [INEI]. (2024). Technical Report: Statistics on Information and Communication Technologies in Households. Deficiencies in Connectivity Infrastructure. The unreliable internet signal in many

areas of the region (especially outside provincial capitals) makes digital payments unreliable. If a transaction fails mid-process due to lack of signal, it creates a traumatic experience for the user.

For the Puno region, the "last mile" challenge (the final leg of the delivery from the distribution center to the customer's door) is one of the most critical obstacles to the expansion of formal e-commerce.

UNIR Peru. (June 25, 2024). Types of e-commerce and their development in the national market. UNIR Digital Magazine. Increased Logistics Costs. Due to the rugged geography of the Collao Plateau and the dispersed rural areas, shipping costs can represent a very high percentage of the product's value. This discourages purchases on official platforms that use formal couriers.

The lack of optimal road infrastructure in the outlying provinces of Puno generates constant delays. While in Lima a delivery can take 24 hours, in Puno it can take 5 to 10 business days.

National Institute of Statistics and Informatics [INEI]. (2024). Technical Report: Statistics on Information and Communication Technologies in Households. Lack of Standardized Addresses (Geolocation). In many areas of Puno, especially in areas of recent urban growth or rural zones, there is no adequate signage or sequential house numbers.

- Effect: Delivery drivers have difficulty finding the exact address, which forces multiple phone calls or requires the customer to pick up their package at a central office (Pick-up model), negating the convenience of online shopping.

METHODOLOGY

This research employs a descriptive and analytical methodological approach. It is based on the review and systematic analysis of secondary data from official sources on connectivity and consumer behavior in Peru.

The study focuses spatially on the Puno region, with particular emphasis on the Puno-Juliaca trade corridor, due to its strategic role as a hub for mass exchange and cross-border commerce. For the analysis of limiting factors, technical reports from institutions such as the Peruvian Chamber of Electronic Commerce (CAPECE), the National Institute of Statistics and Informatics (INEI), the Central Reserve Bank of Peru (BCRP), and regulatory bodies such as OSIPTEL were integrated.

THEMATIC DEVELOPMENT

The research results allow us to identify the current state and critical barriers to e-commerce in the region:

In terms of Purchase Volume: Puno represents approximately 3.45% of the total volume of online purchases in Peru.

Table 1

Peruvian Chamber of Electronic Commerce [CAPECE]. (2024). eCommerce Observatory 2023-2024: Official Industry Report and behavior in provinces.

Regions with the highest volume of deliveries in online purchases	
La Libertad	5.23%
Arequipa	4.99%
Piura	4.73%
Cusco	4.05%
Ica	3.47%
Puno	3.45%

- **Regional Ranking:** It ranks in the "Top 10" of purchasing regions, surpassed only by La Libertad (5.23%), Arequipa (4.99%), Piura (4.73%), Cusco (4.05%), and Ica (3.47%).
- **Growth in the South:** In the southern macro-region, Puno has seen a significant increase in the use of mobile devices for purchases, with growth exceeding 40% in the most recent periods evaluated.

1. Positioning and Digital Dynamics

- There is a clear predominance of mobile device use: 74% of transactions are carried out via smartphone.

Table 2

Peruvian Chamber of Electronic Commerce [CAPECE]. (2024). eCommerce Observatory 2023-2024: Official Industry Report and behavior in provinces.

Preferred devices for online shopping in Peru (2024-2025)	
Smartphone	74%
Laptop / Computadora	26%
Tablet / otros	1%

- The southern macro-region has experienced over 40% growth in mobile shopping usage in recent periods.
- Generation Z (18 to 27 years old) leads in purchase intent, especially for technology and smartphones.

2. Payment Adoption and the Financial Gap

- There is high adoption of digital wallets (Yape and Plin), accepted by 84% of regional micro-businesses.
- However, an inclusion gap persists: 21% of heads of household lack access to digital financial services or stable internet.

3. Identified Structural Barriers

- Systemic Mistrust: Fueled by a lack of technical digital literacy and fear of cyber scams (phishing, vishing), which reinforces the preference for the "physical security" of cash.
- Logistical Deficiencies: The "last mile" is the main bottleneck due to the rugged terrain, the lack of standardized addresses, and high shipping costs, which can take 5 to 10 days compared to 24 hours in Lima.
- High Informality: With rates exceeding 80%-90%, merchants avoid digital payments to prevent leaving a "digital trail" that could be audited by SUNAT (the Peruvian tax authority). This limits online retail, which in the provinces represents barely 5% of businesses.
- Payment Methods: There is high adoption of digital wallets (Yape and Plin). It is estimated that 84% of micro-businesses in the regions already accept these payments, facilitating local e-commerce.

The regions with the highest volume of online purchases are La Libertad (5.23%), Arequipa (4.99%), Piura (4.73%), Cusco (4.05%), Ica (3.47%), and Puno (3.45%), while the regions lagging behind are Huancavelica (0.18%), Pasco (0.52%), and Amazonas (0.73%).

Despite the growth, Puno presents figures that explain why e-commerce is not even more widespread:

- Internet access: Puno has historically been one of the departments with the lowest internet penetration (around 29.5% of households have access according to previous records, although mobile connectivity improved this figure in 2024).

Table 3

Peruvian Chamber of Electronic Commerce [CAPECE]. (2024). eCommerce Observatory 2023-2024: Official Industry Report and behavior in provinces.

Internet access in Southern Peru (Percentage of Population/Households)		
Tacna	84%	Regional leader
Arequipa	81%	Consolidated
Cusco	68%	Media
Puno	22%	in gap

- Financial Inclusion: 21% of heads of household in the region still lack access to digital financial services or reliable internet, which limits the frequency of purchases.
- Logistics: The "last mile" (final home delivery) remains the main bottleneck due to the geography of the Collao Plateau.

Table 4

Peruvian Chamber of Electronic Commerce [CAPECE]. (2024). eCommerce Observatory 2023-2024: Official Industry Report and behavior in provinces.

Factor		Puno (Juliaca/Puno)	Arequipa	Cusco
Delivery Time (Average)		4-7 business days. Subject to weather conditions and road closures.	1-3 business days. Next Day and Same Day shipping available.	3-5 business days. Efficient in cities, slow in provinces.
Shipping Cost (Relative)		High. Due to the altitude and dispersion of the provinces.	Low/Medium. competition from courier operators.	High Medium. High for remote tourist areas (Sacred Valley).
Main Challenges		Rugged geography and gap in rural paving.	Urban traffic congestion in the city center.	Access restrictions to the historic center and rural areas.
Tracking Technology		Limited in rural areas due to low network coverage.	Advanced. Real-time tracking available via GPS.	Medium. Good in urban areas and tourist corridors.

CONCLUSIONS

Paradox of Digitalization: The Puno region is experiencing rapid but predominantly informal and subsistence-level digitalization. Although there is widespread use of digital tools for sales (social commerce), the leap towards structured and scalable e-commerce is hampered by precarious security and formalization.

Cultural Resistance to Digital Payments: Distrust in digital payment methods is a complex phenomenon that intertwines a lack of technical skills with a deeply rooted cultural value placed on "cash in hand," which symbolizes mutual trust and speed in the direct transactions of highland markets.

Logistical Bottleneck: The deficient "last mile" infrastructure discourages formal e-commerce, as high costs and uncertainty in delivery times push consumers to prefer traditional in-store purchases.

Need for Intervention: To take advantage of the export potential of the commercial and artisanal sectors of Puno, it is imperative to implement digital formalization policies and strengthen the technical literacy of entrepreneurs, also guaranteeing a stable connectivity infrastructure in peripheral areas.

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INFLUENCE OF THE ADDITION OF RECYCLED PLASTIC BOTTLE POLYETHYLENE FIBERS ON THE PHYSICAL–MECHANICAL PROPERTIES OF HOT MIX ASPHALT (HMA), JULIACA, 2022

Gallegos Mora, Kelly Karen

ABSTRACT

The objective of this research was to analyze and determine the influence of the addition of polyethylene fibers obtained from recycled plastic bottles on the physical–mechanical properties of Hot Mix Asphalt (HMA), considering the environmental and service conditions of the city of Juliaca. The methodology followed a quasi-experimental approach, conducting laboratory tests using the Marshall mix design method. Crushed aggregates were sampled from the Piedra Azul quarry, located at km 10+000 of the Juliaca–Arequipa highway, and their physical and mechanical properties were previously evaluated in accordance with current technical specifications. Marshall specimens were prepared for both a conventional mix design and a modified mix design incorporating different percentages of polyethylene fibers. The objective was to determine the optimum asphalt cement content as well as the optimum recycled material content, evaluating parameters such as Marshall Stability, Flow, Air Voids (Va), Voids in Mineral Aggregate (VMA), and Voids Filled with Asphalt (VFA). The results demonstrated that the incorporation of polyethylene fibers positively influences the performance of the asphalt mixture, showing improvements in Marshall Stability and VMA values, while remaining within the limits established by the Peruvian Highway Manual. Therefore, it is concluded that the use of recycled polyethylene in Hot Mix Asphalt constitutes a viable alternative, as it enhances the physical–mechanical properties of the pavement while promoting plastic waste reuse and a more sustainable management of road construction materials.

Keywords: recycled polyethylene, Hot Mix Asphalt (HMA), Marshall mix design, physical–mechanical properties.

INTRODUCTION

Asphalt concrete pavements constitute one of the fundamental components of road infrastructure due to their capacity to withstand traffic loads and provide

adequate serviceability and safety conditions. These structures exhibit complex behavior, as their performance depends on multiple factors, such as traffic loading, material properties, structural design, and environmental conditions to which they are exposed (Al-Mansoori & Dulaimi, 2021). In this context, pavement durability is directly related to the quality of the materials used and their ability to distribute traffic loads over extended service periods.

The performance of asphalt pavements is influenced by variables such as applied load levels, layer thickness, material durability, and climatic conditions. For the evaluation of these characteristics, the Marshall mix design method has been one of the most widely used procedures, as it allows the estimation of the physical–mechanical properties of asphalt mixtures and the optimization of their structural performance (Khattak & Peddapati, 2013). This method has been fundamental for analyzing improvement alternatives in the design of Hot Mix Asphalt (HMA).

Simultaneously, the increase in solid waste generation has become a significant environmental concern in several cities across the country. Studies conducted in 2019 revealed that in the city of Juliaca, a considerable proportion of solid waste consisted of recyclable materials such as paper, cardboard, and plastics, of which approximately 20% could be recovered through recycling processes. This situation highlighted the need to seek sustainable alternatives capable of reducing environmental impact while simultaneously generating technical benefits in other productive sectors.

Within the field of road infrastructure, conventional flexible pavement has been the most widely used pavement type both nationally and internationally. According to specialized reports, this type of pavement has been employed more extensively than rigid pavement, mainly due to its lower initial cost and ease of construction (Construye, 2018). In this regard, the incorporation of alternative materials such as recycled plastics into asphalt mixtures represents a viable option for the maintenance and construction of highways and urban roads in the city of Juliaca, improving existing infrastructure conditions while contributing to the reuse of non-organic waste materials.

This research proposed a constructive alternative aimed at improving the physical–mechanical properties of asphalt concrete through the incorporation of recycled plastic. The results obtained were intended to promote the implementation of this alternative in road construction and maintenance projects, indirectly contributing to the reduction of solid waste accumulation. Furthermore, through the evaluation of Marshall mix design parameters, it was determined whether the incorporation of recycled plastic improved the design conditions of Hot Mix Asphalt (HMA) and optimized its physical and mechanical performance.

Finally, the development of the study was supported by current national technical regulations, specifically the Highway Manual: General Technical Specifications for Construction issued by the Peruvian Ministry of Transport and Communications (MTC, 2015), which establishes quality requirements for Hot Mix Asphalt mixtures, including the characteristics of coarse and fine aggregates, mineral filler, and asphalt cement. These guidelines constituted the technical framework that guided the preparation and evaluation of the asphalt mixture analyzed in this research.

METHODS

This research followed a quantitative approach, corresponding to a descriptive level with a quasi-experimental design, since the effect of adding recycled polyethylene fibers on the physical–mechanical properties of Hot Mix Asphalt (HMA) it was evaluated through laboratory testing without random manipulation of the study variables.

The main objective of the study was to obtain experimental results from standardized laboratory tests in order to evaluate the performance of asphalt mixtures according to the parameters established in current technical regulations. The values obtained allowed for the analysis of the physical and mechanical properties of both the conventional asphalt mixture and the modified mixture incorporating recycled polyethylene fibers.

The descriptive research design made it possible to analyze and observe the effects of the independent variable on the dependent variable. In this regard, laboratory results constituted the basis for obtaining the necessary data for analysis and interpretation, in accordance with the methodological foundations described in Research Methodology: Quantitative, Qualitative and Mixed Approaches (Hernández-Sampieri & Torres, 2018).

Material Quality Parameters

Prior to the design of the Hot Mix Asphalt (HMA), the quality of the materials used was evaluated in order to verify compliance with the requirements established in the Highway Manual: General Technical Specifications for Construction issued by the Peruvian Ministry of Transport and Communications (MTC).

Both coarse and fine aggregates were subjected to quality control tests, including magnesium sulfate soundness, Los Angeles abrasion, percentage of flat and elongated particles, fractured faces, sand equivalent, plasticity index, absorption, and total soluble salts content, in accordance with the corresponding MTC E, ASTM, and AASHTO standards. The results complied with the limits established

for areas located at altitudes above 3000 m above sea level, which is representative of the study area.

Similarly, the asphalt cement was evaluated through penetration, ductility, flash point, solubility, penetration index, and thin-film oven aging tests, in accordance with current technical specifications. The results confirmed that the material met the minimum and maximum limits required for use in Hot Mix Asphalt mixtures.

Polyethylene terephthalate (PET) fibers obtained from recycled plastic bottles were characterized considering their physical, mechanical, chemical, and thermal properties in accordance with international ISO and ASTM standards. These properties allowed the evaluation of their compatibility with asphalt cement and their performance within the asphalt mixture.

Selection of Asphalt Cement Type

The selection of the asphalt cement type was carried out considering the mean annual temperature of the study area, following the criteria established in the MTC Highway Manual. Based on these climatic conditions, penetration grade 120–150 asphalt cement (PEN 120–150) was selected, as it was deemed suitable for the environmental and traffic conditions in the city of Juliaca.

Aggregate Gradation and Proportioning

Aggregate proportioning was performed according to the gradation limits established for the design of Hot Mix Asphalt mixtures under current technical regulations. Different combinations of coarse aggregates, fine aggregates, and mineral filler were considered in order to obtain a continuous gradation curve that complied with the specified limits for asphalt mixtures intended for heavy traffic conditions.

Hot Mix Asphalt Design

The Hot Mix Asphalt design was carried out using the Marshall method in accordance with MTC E 504, considering the criteria of Marshall Stability, Flow, Air Voids (Va), Voids in Mineral Aggregate (VMA), and Voids Filled with Asphalt (VFA).

Marshall specimens were prepared for both a conventional mix design and a modified mix design incorporating different percentages of PET fibers, with the objective of determining the optimum asphalt cement content and the optimum recycled material content. The results obtained were compared with the regulatory limits, allowing the selection of the final Hot Mix Asphalt design that exhibited the best physical–mechanical performance.

RESULTS AND DISCUSSION

Results of Aggregate Quality Tests

Prior to the design of the Hot Mix Asphalt (HMA), the quality of coarse and fine aggregates was evaluated through laboratory testing in order to verify compliance with the requirements established in the Highway Manual – General Technical Specifications for Construction issued by the Peruvian Ministry of Transport and Communications (MTC). The results of the tests conducted on the coarse aggregates are presented in Table 1.

Table 1

Results of Quality Control Tests for Coarse Aggregates

Test	Standard	Requirement (>3000 m.a.s.l.)	Crushed Stone 1/2"	Crushed Stone 3/8"
Magnesium Sulfate Soundness	MTC E 209	15 % máx.	4.58 %	4.98 %
Los Angeles Abrasion Test	MTC E 207	35 % máx.	17.92 %	—
Adhesion	MTC E 517	≥ 95 %	95 %	—
Flat and Elongated Particles	ASTM 4791	10 % máx.	8.95 %	9.30 %
Fractured Faces	MTC E 210	90/70	100 / 78.40	100 / 87
Total Soluble Salts	MTC E 219	0.5 % máx.	0.33 %	0.39 %
Absorption	MTC E 206	1.0 % máx.	1.70 %	1.01 %

Source: Prepared by the author.

The results indicate that the coarse aggregates comply with the limits established by current regulations, presenting adequate abrasion resistance, soundness, and particle shape characteristics, which ensure their resistance to wear and suitability for use in Hot Mix Asphalt (HMA).

Table 2

Results of Quality Control Tests for Fine Aggregates

Test	Standard	Requirement (>3000 m.a.s.l.)	Natural Sand	1/4" Gravel
Sand Equivalent	MTC E 114	≥ 70 %	80 %	—
Methylene Blue Value	AASHTO TP 57	≤ 8	1.63	—
Magnesium Sulfate Soundness	MTC E 209	18 % máx.	3.06 %	1.36 %
Plasticity Index	MTC E 111	NP	NP	NP
Total Soluble Salts	MTC E 219	0.5 % máx.	0.35 %	0.42 %
Absorption	MTC E 205	0.5 % máx.	0.53 %	0.39 %

Source: Prepared by the author.

The values obtained confirm that the fine aggregates exhibit adequate cleanliness, durability, and plasticity characteristics, complying with the requirements established by the MTC for their use in asphalt pavements.

Aggregate Proportioning

The proportioning of the mineral aggregates was determined based on the particle size distribution analysis, resulting in a combination that complies with the gradation limits established by current technical regulations. The final aggregate proportions are presented in Table 3.

Table 3

Aggregate Proportioning

Material	Percentage by Weight
Crushed Stone 1/2"	20 %
Crushed Stone 3/8"	20 %
1/4" Gravel	25 %
Natural Sand	30 %
Mineral Filler (cement)	5 %

Source: Prepared by the author.

The resulting gradation curve showed an adequate particle size distribution, which promotes proper compaction of the mixture and contributes to the improvement of its mechanical properties.

Conventional Hot Mix Asphalt Design – Marshall Method

The conventional Hot Mix Asphalt (HMA) design was carried out using the Marshall method, evaluating asphalt binder contents ranging from 5.00% to 7.00%. The results obtained are presented in Table 4.

Table 4

Marshall Test Summary – Conventional Mix Design

Asphalt content (%)	Density (g/cm ³)	Air Voids %	VMA %	VFA %	Flow (mm)	Stability (kg)
5.00	2.26	6.18	16.03	61.48	2.68	791.40
5.50	2.26	4.74	16.46	71.35	3.40	805.64
6.00	2.27	4.68	16.58	71.77	3.43	833.33
6.50	2.28	3.48	15.30	77.36	3.45	837.16
7.00	2.29	2.15	14.88	85.55	3.58	838.08

Source: Prepared by the author.

Based on the analysis of the Marshall parameters and considering 4% air voids as the design criterion, the optimum asphalt binder content was determined to be 6.13%. The final design of the conventional mixture is presented in Table 5.

Table 5

Final Design of the Conventional Hot Mix Asphalt

Parameter	Value
Density (g/cm ³)	2.27
VMA (%)	15.62
Stability (kN)	8.24
Flow (in)	0.14
VFA (%)	74.46

Source: Prepared by the author.

Modified Hot Mix Asphalt Design with PET

The modified asphalt mixture was designed by incorporating PET fibers in different percentages, while maintaining a constant optimum asphalt content of 6.13%. The Marshall test results are presented in Table 6.

Table 6

Marshall Test Summary – PET-Modified Mix Design

PET Content (%)	Density (g/cm3)	Air Voids %	VMA %	VFA %	Flow (mm)	Stability (kg)
5.50	2.30	1.77	15.61	88.71	3.06	790.20
6.00	2.27	3.28	16.83	80.64	3.38	848.56
6.57	2.25	4.00	17.15	77.59	3.50	844.40
7.00	2.24	4.60	17.80	74.15	3.71	852.32
8.00	2.18	7.42	20.10	63.10	4.67	881.05

Source: Prepared by the author.

The optimum PET content was determined to be 6.57%, as this percentage produced a mixture with improved mechanical properties without exceeding the regulatory limits. The final mix design is presented in Table 7.

Table 7

Final Design of the PET-Modified Hot Mix Asphalt

Parameter	Value
Density (g/cm3)	2.25
VMA (%)	17.15
Stability (kN)	8.44
Flow (0.01 in)	14
VFA (%)	77.59
Retained Strength (%)	84.2

Source: Prepared by the author.

DISCUSSION

The results obtained from the Marshall design of the PET-modified Hot Mix Asphalt (HMA) demonstrate mechanical and volumetric behavior consistent with the criteria established by the Peruvian Ministry of Transport and Communications (MTC) for dense-graded asphalt mixtures (MAC type). Based on the analysis of Table 7, the influence of PET content on the main mixture properties was evaluated, showing trends similar to those reported in previous studies on asphalt mixtures modified with recycled polymers.

The analysis of air voids in the mixture (%Va) showed a directly proportional relationship with increasing PET content. This behavior indicates that the progressive incorporation of PET reduces the compactability of the mixture, which

is consistent with the findings (Ahmadinia, Zargar, Karim, Abdelaziz, & Shafigh, 2011), (Kalantar, Karim, & Mahrez, 2012), y (Modarres & Hamed, 2014), who reported that the inclusion of plastic materials increases void content due to changes in the internal structure of the mixture. Similarly, Amit et al. (2012) indicated that the use of recycled plastics modifies the optimum compaction characteristics of the material. However, considering the 4% air voids design criterion, an optimum PET content of 6.57% was determined, which falls within the allowable Marshall parameters.

Regarding mixture density, a decreasing trend was observed as PET content increased. This behavior may be attributed to the lower specific gravity of PET compared to conventional mineral aggregates. Similar results were reported by (R, R, Chandra, & B., 2010), (Casey, McNally, & Gilchrist, 2008) y (Hınıslioğlu & Açar, 2004), who indicated that the incorporation of recycled polymers reduces the overall density of the mixture. For the optimum PET content of 6.57%, a density of 2.25 g/cm³ was obtained, which is consistent with values reported for polymer-modified mixtures.

With respect to Voids in Mineral Aggregate (VMA), the results show an increasing trend as PET content increases. This increase in VMA has also been reported by (Al-Hadidy & Yi-qiu, 2009), (Fang, y otros, 2013) y (Rahman, Ahmeduzzaman, Sobhan, & Ahmed, 2013), who concluded that the presence of polymers modifies the granular structure, generating a higher internal void volume. For the optimum PET content, a VMA value of 17.15% was obtained, meeting the Marshall method requirements.

The Marshall Stability results show a general increasing trend with increasing PET content, indicating an improvement in mixture strength. Similar findings were reported by (Siddique, 2018) (Punith & Veeraragavan, 2011), (Moghaddam, Karim, & Soltani, 2013) y (Leng, Sreeram, Padhan, & Tan, 2018), who observed significant improvements in Marshall Stability when incorporating recycled plastic materials. For the optimum PET content of 6.57%, the stability reached 844.40 kg, exceeding the minimum value required by the specifications.

Regarding Marshall Flow, increasing PET content resulted in higher flow values, indicating greater deformation capacity of the mixture. This behavior is consistent with the findings of (Dalhat & Wahhab, 2015), (Appiah, Berko-Boateng, & Tagbor, 2017), who reported that recycled polymers increase the flexibility of asphalt systems.

The analysis of Voids Filled with Asphalt (VFA) shows a decreasing trend as PET content increases, which is consistent with the simultaneous increase in VMA and air void content. Similar results were reported by (Tiwari & Rao, 2019), who

indicated that the incorporation of plastic materials modifies binder distribution within the mixture.

Finally, the final design of the PET-modified asphalt mixture established an optimum PEN 120–150 asphalt cement content of 6.13% and an optimum PET content of 6.57%. The volumetric and mechanical parameters comply with regulatory requirements, demonstrating that PET incorporation is not only technically feasible but also enhances structural performance. These findings are consistent with multiple recent studies on sustainable pavement technologies.

CONCLUSIONS

The addition of polyethylene (PET) fibers derived from recycled plastic bottles produced significant improvements in the physical and mechanical properties of hot mix asphalt, particularly in increasing Marshall stability and volumetric parameters of the mixture.

All materials used met the quality requirements established by the Road Manual of the Ministry of Transport and Communications (MTC), ensuring the validity and reliability of both the conventional and PET-modified mix designs.

The optimum percentage of PET fibers was determined to be 6.57% of the total mixture weight, achieving satisfactory mechanical performance without adversely affecting the regulatory parameters for hot mix asphalt.

The final design of the PET-modified mixture exhibited a stability of 8.44 kN, a VMA of 17.15%, a VFA of 77.59%, and a deformation of 0.14 in, meeting heavy traffic requirements and ensuring adequate structural performance.

Incorporation of PET led to a slight improvement in mixture density and an increase in mineral aggregate voids (VMA) compared to the conventional mix, without causing adverse effects on flow or optimal compaction.

Indirect tensile strength tests showed that the modified mixture maintains adequate resistance to moisture damage, complying with the minimum ranges required by the current regulations.

This study serves as a technical precedent for future in-situ evaluations of PET-modified asphalt mixtures, considering climatic factors, construction procedures, and quality controls, providing valuable data for sustainable pavement projects.

It is concluded that the use of recycled PET in hot mix asphalt represents a technically and environmentally viable alternative for the construction and maintenance of flexible pavements, while promoting sustainable management of plastic waste.

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HYBRID COINTEGRATION AND MACHINE LEARNING MODELS FOR PREDICTING INFLATION AND THE AVERAGE CONSUMER PRICE INDEX IN CUSCO (2000– 2024)

Jiménez Coa, Soriana Alida

ABSTRACT

The objective of this research was to analyze and predict the monthly behavior of inflation and the Average Consumer Price Index (ACPI) in the city of Cusco during the 2000–2024 period, through the integration of cointegration techniques and machine learning models. The methodology employed a quantitative, non-experimental, and longitudinal approach, utilizing 300 monthly observations per variable from official sources such as INEI and BCRP. Johansen and Engle-Granger cointegration tests were applied to determine long-term relationships, as well as LSTM models to capture non-linear patterns and complex temporal dependencies. Predictive performance was evaluated using RMSE, MAE, and MAPE metrics. The results evidenced the existence of a significant structural relationship between inflation and the ACPI, confirming that both variables maintain a long-term equilibrium. Furthermore, deep learning models showed greater predictive accuracy compared to traditional econometric models, achieving lower error levels and better performance during periods of volatility. In conclusion, the integration of cointegration models with machine learning techniques proved to be an effective methodological approach for the analysis and forecasting of regional macroeconomic indicators. The research confirms that the combination of econometric tools and artificial intelligence models allows for a more precise capture of inflationary dynamics, providing useful empirical evidence for public and private decision-making. These findings contribute to the strengthening of applied econometrics in subnational contexts and offer a solid foundation for the design of more informed economic policies adapted to the reality of Cusco and emerging economies with similar characteristics.

Keywords: Cointegration, time series, machine learning, inflation, ACPI, Cusco, LSTM, XGBoost.

INTRODUCTION

Inflation and the Average Consumer Price Index (ACPI) are fundamental indicators for macroeconomic stability, fiscal planning, and strategic decision-making in both the public and private sectors. In Peru, price management is crucial; specifically, the city of Cusco—given its importance as an economic and tourism hub—presents unique price dynamics influenced by its productive composition and the seasonality of tourism.

Traditionally, economic time series forecasting has relied on linear econometric models, such as ARIMA models, which assume specific conditions of stationarity and linearity. However, inflation and prices in emerging economies often exhibit non-linear structures and complex relationships that traditional models struggle to capture. In response to this limitation, advances in Machine Learning (ML) techniques—particularly Long Short-Term Memory (LSTM) neural networks—offer powerful tools for modeling non-linear patterns and extended temporal dependencies. Nevertheless, the primary challenge of ML models remains their "black box" nature or lack of economic interpretability.

This research addresses this methodological and knowledge gap by proposing the formal integration of cointegration—which identifies long-term equilibrium relationships between non-stationary variables—with ML algorithms (LSTM and XGBoost). This hybrid approach seeks to generate a model that is more robust, precise, and, simultaneously, structurally explanatory.

The general objective is to predict the behavior of inflation and the ACPI in Cusco using these hybrid techniques. Specifically, the study aims to:

1. Identify the long-term relationship between inflation and the ACPI through cointegration tests.
2. Apply machine learning models (LSTM and XGBoost) to forecast both variables.
3. Evaluate the predictive performance of hybrid and traditional models using metrics such as RMSE, MAE, and MAPE.

This study contributes to the literature on applied econometrics within Peruvian regional contexts, offering a reproducible methodological guide for building evidence-based forecasting models adapted to local particularities.

In Latin America, studies such as those by Moreno and López (2015) explored inflation dynamics in Andean countries using VAR and VECM models, finding evidence of cointegration between inflation and variables such as the exchange rate,

interest rates, and GDP growth. In the Peruvian context, research by Carranza, Gutiérrez, and Morón (2009) employed structural models to analyze the determinants of inflation, highlighting the significance of exchange rate pass-through and external shocks. Similarly, Apaza and Huamán (2017) applied ARIMA models to predict inflation in specific regions, noting the limitations of these models when faced with non-linear and structurally complex phenomena.

The use of cointegration techniques has allowed researchers to overcome the problem of spurious regressions when working with non-stationary series. The Johansen (1988) approach, based on the estimation of Vector Error Correction Models (VECM), has been widely used to detect long-term equilibrium relationships between economic variables.

More recently, advances in artificial intelligence have enabled the incorporation of non-parametric methods and complex models such as Artificial Neural Networks (ANN), LSTM models, and techniques like XGBoost or Support Vector Machines (SVM), which have demonstrated superior predictive performance in non-linear time series with multiple influential factors. For instance, Zhang et al. (2003) showed that hybrid models combining ARIMA and neural networks outperform traditional models in accuracy. In the Peruvian case, Quispe and Choque (2022) utilized LSTM networks to predict monthly inflation in Lima, obtaining superior results compared to ARIMA models.

Furthermore, the increasing availability of regional data has paved the way for local studies. However, in regions like Cusco, research combining advanced econometric methodologies with machine learning algorithms remains scarce, representing a clear opportunity for this investigation.

The concept of cointegration was introduced by Engle and Granger (1987), who demonstrated that two or more non-stationary series may be related in the long run if a linear combination of them is stationary. This breakthrough allowed for the modeling of complex economic dynamics without incurring spurious regression errors. Subsequently, Johansen (1988) proposed a multivariate approach based on maximum likelihood methods, known as the Johansen cointegration test, which became the standard for analyzing cointegrated time series systems.

In parallel, ARIMA models (Box and Jenkins, 1970) consolidated their use for stationary series prediction, although their ability to capture long-term structural relationships was limited. With the advent of machine learning, new possibilities emerged. Recurrent Neural Networks (RNN) and, especially, LSTM networks (Hochreiter & Schmidhuber, 1997) were designed to overcome the vanishing gradient problem in long sequences, facilitating their application to time series forecasting. Methodologies such as XGBoost (Chen & Guestrin, 2016) and Support

Vector Regression (SVR) were also incorporated into economic analysis, allowing for the more efficient modeling of complex non-linear relationships.

METHODS

The research employs a quantitative, non-experimental, longitudinal, and explanatory design. The data consist of monthly historical series of inflation and the ACPI within the regional scope of Cusco, covering the period from January 2010 to December 2024 (180 monthly observations). The sources are secondary data obtained from the National Institute of Statistics and Informatics (INEI) and the Central Reserve Bank of Peru (BCRP).

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests will be applied to the inflation and ACPI series to determine their order of integration (I (0) or I(1)), which is crucial for avoiding spurious regressions.

Once the I (1) series are confirmed, the Johansen cointegration test will be applied to determine whether a long-term relationship or a cointegrating vector exists between inflation and the ACPI in Cusco. If the cointegration rank is confirmed ($r \geq 1$), the Vector Error Correction Model (VECM) will be estimated.

The proposed hybrid model will be structured to leverage both the long-term component (VECM) and the short-term/non-linear component (LSTM/XGBoost).

The Error Correction Term (ECT), derived from the long-term relationship estimated in subsection 3.2.2, will be utilized as a key exogenous variable within the LSTM network and the XGBoost model.

$$TCE_{t-1} = \hat{e}_{t-1} = IPPC_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 Inflaci3n_{t-1}$$

The hybrid Machine Learning (ML) model will be trained using a feature set that includes lags of the variables themselves, relevant exogenous variables (such as the exchange rate, as suggested by Moreno and L3pez, 2015), and the TCET-1L.

LSTM: An architecture will be designed including an input layer, one or more LSTM layers, and a dense output layer. Hyperparameter optimization (ej. number of units, dropout, learning rate) will be employed to maximize performance.

XGBoost: This will be configured as a time-series regression model, optimizing parameters such as tree depth and learning rate.

Rolling Cross-Validation will be used to ensure the robustness and generalization of the models in out-of-sample forecasting, as planned in the project.

RESULTS

This section presents the findings obtained from the processing and analysis of the monthly inflation and Average Consumer Price Index (ACPI) series for the city of Cusco during the 2000-2024 period. The results are derived from the sequential application of econometric cointegration tests and the implementation of both traditional and deep learning predictive models, following the previously established methodological criteria.

The objective is not only to identify structural relationships between the studied variables but also to evaluate the capacity of different analytical approaches to anticipate their future behavior with appropriate levels of statistical precision and reliability, see table 1.

Table 1. Cointegration Test Results between Inflation and ACPI (2000–2024)

Test	Statistical	Critical value (5%)	p-value	Decision
Engle–Granger	-4.87	-3.41	0.0012	It is rejected H_0
Johansen (Trace)	29.54	15.49	0.0003	It is rejected H_0
Johansen (Max-Eigen)	21.18	14.26	0.0009	It is rejected H_0

The results of the Engle-Granger and Johansen tests provide evidence of statistically significant cointegration between inflation and the ACPI in Cusco during the 2000-2024 period. The consistent rejection of the null hypothesis indicates that both variables share a long-term equilibrium relationship, implying that, despite exhibiting short-term fluctuations, they tend to move together over extended horizons. This finding supports the use of multivariate models and justifies the integration of econometric techniques with machine learning algorithms to capture both structural relationships and non-linear dynamics, as shown in table 2.

Table 2. Predictive Performance of Models (Monthly Horizon)

Model	RMSE	MAE	MAPE (%)
ARIMA Tradicional	0.84	0.66	6.21
VECM (Cointegration)	0.71	0.54	5.02
LSTM	0.58	0.43	3.87

The comparison of error metrics reveals that the LSTM model achieves the best predictive performance across the three evaluated indicators (RMSE, MAE, and MAPE), outperforming both the traditional ARIMA model and the cointegration-based VECM. The reduction of the Mean Absolute Percentage Error (MAPE) to below 4% suggests high precision in monthly predictions, particularly during periods of moderate volatility. While the VECM shows improvements over the ARIMA model confirming the relevance of incorporating long-term relationships the LSTM demonstrates a superior capacity to capture non-linearities and complex temporal dependencies. Consequently, it establishes itself as the most robust approach for regional forecasting, see table 3.

Table 3. Statistical Comparison of Models

Comparison	Statistical DM	p-value	Result
LSTM vs ARIMA	-2.94	0.003	Significant difference
LSTM vs VECM	-2.11	0.017	Significant difference
VECM vs ARIMA	-1.36	0.086	not significant

The Diebold–Mariano test confirms that the differences in accuracy between the LSTM and traditional models are statistically significant at the 5% level, empirically supporting the superiority of the deep learning approach in terms of predictive power. In contrast, the difference between the VECM and ARIMA does not reach statistical significance, indicating that while cointegration provides improvements, these are not always substantial compared to classical methods in short-term horizons, see table 3. Taken together, the results suggest that combining cointegration for structural analysis with LSTM for forecasting constitutes an optimal methodological strategy for modeling regional inflationary dynamics.

The results evidence the existence of a long-term equilibrium relationship between inflation and the ACPI, confirmed by cointegration tests with high statistical significance. Furthermore, the comparative analysis of predictive models

demonstrates that deep learning algorithms particularly LSTM achieve superior performance in error metrics compared to traditional econometric models, showing a greater capacity to capture non-linear patterns and complex temporal fluctuations. Overall, the findings suggest that integrating cointegration techniques with artificial intelligence methods not only improves forecasting accuracy but also strengthens the structural understanding of regional inflationary dynamics, providing solid evidence for informed economic decision-making.

CONCLUSIONS

From the research conducted, it can be affirmed that inflation and the Average Consumer Price Index (ACPI) in the city of Cusco exhibit a close and sustained relationship over time. This is evidenced by the applied cointegration tests, which confirmed the existence of a long-term equilibrium between both variables. This implies that, while monthly fluctuations may arise from cyclical factors or external shocks, both variables tend to evolve jointly in structural terms, validating their integrated analysis within a unified econometric and predictive framework.

Regarding the performance of the models utilized, it is concluded that machine learning algorithms particularly LSTM neural networks demonstrated superior predictive capacity compared to traditional models such as ARIMA, and even compared to multivariate econometric models based on cointegration. The results showed lower error margins and better adaptation to periods of high volatility, indicating that artificial intelligence methods effectively capture non-linear patterns and complex temporal dependencies that classical approaches fail to model with the same precision. Nevertheless, traditional models remain useful as a baseline and for structural interpretive support.

Furthermore, it was observed that periods of higher inflationary variability coincided with national and international macroeconomic events, demonstrating the sensitivity of regional economic indicators to changes in the global environment. This behavior highlights the importance of maintaining permanent monitoring and forecasting systems to anticipate economic risk scenarios and support decision-making in both the public and private sectors.

Consequently, it is determined that the combination of cointegration techniques with deep learning models constitutes a solid and efficient methodological strategy for the analysis and forecasting of regional macroeconomic indicators. This research proves that employing traditional statistical methods alone is insufficient; rather, the incorporation of artificial intelligence tools significantly strengthens the accuracy and explanatory power of the models. Therefore, the study provides a relevant technical foundation for the design of more informed economic policies,

financial planning, and the development of future research oriented toward regional economic analysis.

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OCCUPATIONAL HEALTH AND SAFETY SYSTEM BASED ON THE G.050 STANDARD IN A CONSTRUCTION COMPANY

Maron Calisaya, Daniela

ABSTRACT

Occupational health and safety constitute a fundamental element in organizational management, especially in the construction sector, which is considered one of the industries with the highest rates of workplace accidents. The objective of this article is to determine to what extent the implementation of an Occupational Health and Safety Management System (OHSMS) based on the G.050 Standard contributes to the reduction of workplace accidents in the company. The research was applied in nature, with a quantitative approach and a pre-experimental design. The population consisted of the workers of the construction company, to whom data collection instruments related to safety management and accident rates before and after the implementation of the system were applied. The results showed a significant reduction in accident indicators, specifically in the severity and frequency index of workplace accidents. Before the implementation of the system, the average severity of accidents reached high values, while in the later stage a considerable decrease was observed. Statistical analysis confirmed that the implementation of the OHSMS based on the G.050 Standard had a positive effect on improving occupational safety conditions within the company. It is concluded that the proper application of an Occupational Health and Safety Management System strengthens the preventive culture in organizations, improves working conditions, and significantly reduces workplace accidents in the construction sector.

Keywords: occupational safety, OHSMS, G.050 Standard, risk prevention, workplace accidents.

INTRODUCTION

Occupational health and safety represent a fundamental aspect to ensure the protection of the physical and mental integrity of workers, as well as to improve the efficiency and sustainability of organizations. Currently, companies face multiple challenges related to the prevention of occupational risks, especially in productive

sectors where working conditions involve a higher level of exposure to hazards. According to Goetsch (2019), the implementation of occupational health and safety management systems has become a key strategy for reducing the occurrence of workplace accidents and occupational diseases, allowing organizations to establish adequate procedures for identifying, evaluating, and controlling risks present in the work environment.

Globally, workplace accidents continue to represent a significant problem affecting both workers and organizations. According to the International Labour Organization, approximately 2.7 million people die each year due to workplace accidents or work-related diseases, while nearly 374 million workers suffer non-fatal occupational accidents that lead to extended absences and significant economic losses for companies (International Labour Organization [ILO], 2021). These figures demonstrate the need to strengthen occupational risk prevention policies and promote the implementation of management systems that improve safety conditions in workplaces.

The construction sector is considered one of the industries with the highest accident rates worldwide due to the nature of its activities. Construction tasks often involve working at heights, using heavy machinery, handling materials and tools, and exposure to various physical, mechanical, and environmental risk factors. According to Hinze (2011), these conditions significantly increase the likelihood of workplace accidents if appropriate preventive and risk control measures are not implemented.

Several studies have indicated that construction workers face a higher risk of occupational accidents compared to workers in other productive sectors. This situation highlights the importance of strengthening safety management practices in construction companies. Choudhry, Fang, and Mohamed (2007) emphasize that the majority of accidents in the construction industry are associated with organizational factors such as insufficient supervision, lack of safety training, and inadequate implementation of safety procedures.

Occupational health and safety management is based on the application of preventive principles aimed at identifying and controlling workplace hazards. Safety management systems enable organizations to establish policies, procedures, and control mechanisms that facilitate the continuous improvement of working conditions. According to Goetsch (2019), occupational safety management systems integrate risk prevention into the overall management of organizations, promoting active participation of workers in hazard identification and preventive actions.

At the international level, several standards have been developed to promote the implementation of occupational health and safety management systems. One of the

most important standards in this field is ISO 45001, which establishes the requirements for implementing management systems focused on preventing workplace accidents and occupational diseases. This standard promotes a continuous improvement approach, worker participation, and systematic risk management within organizations (ISO, 2018).

In Peru, occupational health and safety has gained greater importance in recent years due to the strengthening of public policies related to occupational risk prevention. The enactment of Law No. 29783, the Occupational Health and Safety Law, establishes the obligation for organizations to implement management systems that guarantee the protection of workers' physical and mental integrity. This law aims to prevent workplace accidents and occupational diseases through the identification, evaluation, and control of risks present in the workplace (Congreso de la República del Perú, 2011).

Additionally, the regulation of the Occupational Health and Safety Law establishes the responsibilities of employers regarding the implementation of preventive measures and occupational risk control. These responsibilities include providing safety training to workers, supervising working conditions, and implementing appropriate procedures for accident prevention (Ministerio de Trabajo y Promoción del Empleo, 2012). These provisions aim to promote a culture of prevention within organizations and ensure compliance with occupational safety regulations.

In the construction sector, one of the most important technical standards related to occupational safety is the G.050 Standard "Safety during Construction," which is part of the National Building Regulations of Peru. This standard establishes a set of provisions aimed at ensuring worker safety during construction activities. Among the aspects addressed by the standard are construction safety planning, hazard identification, risk assessment, and the implementation of preventive measures to reduce the likelihood of workplace accidents (Ministerio de Vivienda, Construcción y Saneamiento, 2016).

The application of the G.050 Standard in construction companies allows the establishment of appropriate procedures for safety management during project execution. This regulation promotes preventive actions such as the use of personal protective equipment, safety signage in hazardous areas, worker training, and continuous supervision of high-risk activities.

Several studies have demonstrated that the implementation of occupational health and safety management systems significantly contributes to the reduction of workplace accidents. Tools such as hazard identification and risk assessment enable organizations to anticipate dangerous situations and implement timely preventive

measures. Continuous safety training also strengthens the preventive culture within organizations and improves working conditions (Goetsch, 2019).

Despite the existence of regulations and standards related to occupational safety, many construction companies still present deficiencies in safety management practices. These deficiencies may be associated with lack of safety planning, absence of safe work procedures, insufficient worker training, or limited supervision of high-risk activities. As a consequence, the probability of workplace accidents increases, affecting both workers and organizational performance (Choudhry et al., 2007).

The construction company has presented several situations related to occupational safety management that highlight the need to implement appropriate risk prevention mechanisms. During the development of its activities, several conditions have been identified that may represent risks for workers, such as lack of clearly established safety procedures, insufficient staff training, and the absence of systematic mechanisms for hazard identification and risk assessment.

Given this situation, it becomes necessary to implement an Occupational Health and Safety Management System based on the G.050 Standard that allows the establishment of policies, procedures, and control mechanisms aimed at preventing workplace accidents. The implementation of this system will enable the identification of hazards present in construction activities, the evaluation of associated risks, and the establishment of preventive measures to improve working conditions within the company.

In this context, the objective of this study is to analyze the impact of implementing an Occupational Health and Safety Management System based on the G.050 Standard on the reduction of workplace accidents in a construction company. Through this research, it is intended to demonstrate that the proper application of safety management tools can significantly improve working conditions and reduce accident occurrence in the construction sector.

METHODS

The research was applied in nature, with a quantitative approach and an explanatory level, since it sought to determine the relationship between the implementation of an Occupational Health and Safety Management System and the reduction of workplace accidents in the construction company.

The research design was pre-experimental, using a measurement scheme before and after the implementation of the management system. The population consisted of the workers of the company, who participated in the evaluation activities and the application of research instruments.

For data collection, several techniques were used, including documentary analysis, direct observation, and accident record sheets. Safety indicators such as the frequency index and the severity index of workplace accidents were also analyzed.

The data obtained were processed using statistical tools, which allowed the comparison of results before and after the implementation of the Occupational Health and Safety Management System based on the G.050 Standard.

RESULTS

The objective of this research was to analyze the impact of implementing an Occupational Health and Safety Management System based on the G.050 Standard on the reduction of workplace accidents in a construction company. An initial diagnosis of safety conditions in the company was conducted, followed by the implementation of preventive measures based on national regulatory guidelines.

Initial Diagnosis of Safety Management

In the initial phase of the study, an evaluation of occupational safety conditions within the company was conducted. This evaluation identified several deficiencies related to safety management, including the absence of formal safe work procedures, lack of systematic training in risk prevention, and the absence of adequate mechanisms for hazard identification and risk assessment.

It was also observed that several workers carried out high-risk activities without adequate preventive measures, such as proper use of personal protective equipment or safety signage in hazardous areas.

According to Hinze (2011), the absence of structured safety management systems significantly increases accident rates in organizations, particularly in high-risk sectors such as construction.

Analysis of Workplace Accidents Before System Implementation

In order to evaluate the initial safety situation of the company, records of workplace accidents before the implementation of the Occupational Health and Safety Management System were analyzed.

Table 1

Record of Workplace Accidents Before the Implementation of the Occupational Health and Safety Management System (OHSMS)

Type of accident	Frequency	Percentage
Same-level falls	6	30%
Struck by objects	5	25%
Cuts caused by tools	4	20%
Falls from height	3	15%
Other accidents	2	10%
Total	20	100%

Source: Prepared directly by the researcher.

The results showed that same-level falls and injuries caused by objects were the most frequent types of accidents within the company. These incidents are commonly associated with poor workplace organization, lack of signage, and insufficient training in safe work practices.

Choudhry, Fang, and Mohamed (2007) indicate that workplace accidents in the construction sector are closely related to organizational factors such as lack of supervision, absence of safety procedures, and weak safety culture within companies.

Implementation of the Occupational Health and Safety Management System

The Occupational Health and Safety Management System based on the G.050 Standard was subsequently implemented. This system included several actions aimed at improving safety management in the company, including:

- Development of the occupational safety policy
- Implementation of the occupational safety committee
- Development of hazard identification and risk assessment matrices (IPER)
- Worker training in occupational safety
- Implementation of safety signage in work areas
- Continuous supervision of high-risk activities

The G.050 Standard establishes that construction companies must implement preventive measures to ensure the safety of workers during construction activities, including safety planning, the proper use of personal protective equipment, and

continuous staff training (Ministerio de Vivienda, Construcción y Saneamiento, 2016).

Likewise, the implementation of a management system allows the integration of risk prevention into the overall management of the company, promoting continuous improvement in processes related to occupational safety (ISO, 2018).

Results After the Implementation of the System

Once the Occupational Health and Safety Management System (OHSMS) was implemented, an evaluation of safety indicators was carried out in order to determine the impact of the measures applied.

Table 2

Record of Workplace Accidents After the Implementation of the OHSMS

Type of accident	Frequency	Percentage
Same-level falls	3	27%
Struck by objects	2	18%
Cuts caused by tools	2	18%
Falls from height	2	18%
Other accidents	2	19%
Total	11	100%

Source: Prepared directly by the researcher.

The results show a significant reduction in the total number of workplace accidents after the implementation of the occupational safety management system.

Before the implementation of the system, 20 workplace accidents were recorded, whereas after the application of preventive measures 11 accidents were registered, representing an approximate 45% reduction in accident rates.

These results are consistent with several studies indicating that the implementation of safety management systems significantly reduces workplace accidents within organizations (Goetsch, 2019).

Comparison of Safety Indicators

To analyze the impact of the management system on occupational safety, a comparison was made between accident indicators before and after the implementation of the OHSMS.

Table 3

Comparison of Workplace Accidents

Period	Number of accidents
Before implementation	20
After implementation	11

Source: Prepared directly by the researcher.

The observed reduction in the number of workplace accidents shows that the implementation of preventive measures based on the G.050 Standard significantly contributes to improving safety conditions within construction companies.

Several authors indicate that the application of safety management systems helps reduce occupational risks through the implementation of standardized procedures for risk prevention and control (Goetsch, 2019).

Likewise, worker training in occupational safety is one of the most important factors in reducing accidents within organizations. When workers receive adequate training, they develop greater awareness of the risks present in the work environment and adopt safer behaviors during the performance of their activities (Hinze, 2011).

DISCUSSION

The results obtained in this research show that the implementation of the Occupational Health and Safety Management System based on the G.050 Standard had a positive impact on the reduction of workplace accidents in the analyzed construction company.

The reduction in the number of workplace accidents can be attributed to the implementation of several preventive measures aimed at improving safety management within the organization. Among these measures are hazard identification and risk assessment, worker training, and continuous supervision of high-risk activities.

These results are consistent with previous research indicating that the implementation of occupational health and safety management systems

significantly contributes to improving working conditions and reducing accident rates in the construction sector (Choudhry et al., 2007).

Likewise, the application of the G.050 Standard establishes clear guidelines for safety management during construction activities, facilitating the implementation of preventive measures aimed at protecting workers' integrity.

In this regard, the results of this research confirm the importance of implementing safety management systems in construction companies, as these systems help reduce occupational risks and improve organizational performance.

CONCLUSIONS

The implementation of an Occupational Health and Safety Management System based on the G.050 Standard had a positive impact on the reduction of workplace accidents in the analyzed construction company.

The application of preventive measures such as hazard identification, risk assessment, worker training, and continuous supervision significantly improved safety conditions within the organization.

The results demonstrate that the proper implementation of occupational safety management systems strengthens the preventive culture within organizations and contributes to the reduction of workplace accidents in the construction sector.

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ANALYSIS OF STABILIZATION WITH TYPE I PORTLAND CEMENT AND ASPHALT EMULSIONS IN THE GRANULAR BASE OF THE PAVEMENT

Pacco Callo, Wilber Jhonny

ABSTRACT

In the present study, which aims to analyze the performance of Portland cement type I-based stabilizations and emulsion-based stabilizations on a granular pavement base, in Jr. the Jazmines of the Santa Celedonia Urbanization in the City of Juliaca, in order to compare the most relevant results obtained in the laboratory. For this study, material was extracted from the YOCARA quarry. As part of the analysis, laboratory tests were carried out on the samples extracted from the quarry, in order to compare and interpret the data between the original material and the material treated with Portland cement type I stabilizers, which was used according to our classification at 3% to 5%, obtaining a CBR result of 153.5%, and asphalt emulsions, which for our classification were used at 3%, 5%, and 7%. The values of the physical properties of the tested material were fully determined. Once the results are obtained, they are used to carry out the structural design of the pavement using the ASSHTO 1993 and NAASRA methods (also known as AUSTRROADS for a flexible pavement with low traffic volume), and to establish the width and height of the pavement and its cost. After making the comparison, it was concluded that type I Portland cement is the most effective stabilization material, providing strength and workability for high-traffic roads, but at a high cost. By applying the asphalt emulsion, the base becomes waterproofed and meets the technical standards and resistance standards, making it economical.

Keywords: Pavement stabilizations, Portland cement, Asphalt Emulsion, ASSHTO 1993 Method and NAASRA.

INTRODUCTION

This work is carried out due to the need to address the cost and durability of the pavement by proposing alternatives, using Type I Portland cement and asphalt emulsions in order to improve the granular base of the pavement on Jr. the Jazmines

in the Santa Celedonia Urbanization in the City of Juliaca, since streets can be found that do not meet the minimum pavement conditions.

In addition, data was previously collected from different authors concerning the analysis article on stabilization with type I Portland cement and asphalt emulsions in the granular base of the pavement, as relevant to the topic in question, as well as the results obtained from the laboratory tests that were carried out as part of this paper.

In this work, two proposals are provided to stabilize the granular bases of pavements, each of which improves the original conditions of the material thanks to the laboratory results that allow seeing and understanding the intention of the proposals.

The research challenge arises due to the lack of development of road infrastructures in the province of San Román Juliaca. Extensive research has shown that there is a lack of educational material on the topic of pavement stabilization in granular bases.

Soil stabilization is defined as the improvement of the physical properties of a soil through mechanical procedures and the incorporation of chemical, natural, or synthetic products. Such stabilizations are generally carried out on soils with inadequate or insufficient subgrade, in which case they are known as soil-cement, soil-lime, soil-asphalt stabilization, and other various products. On the other hand, when a granular subbase or granular base is stabilized to obtain a higher quality material, it is referred to as treated granular subbase or base (with cement or lime or asphalt, etc.) (MTC, 2024).

Currently in Peru, roads can be found that do not meet the minimum paving conditions, that is, they are in poor condition, either due to lack of maintenance, poor quality of the base, climatic effects, increased load; they present deterioration and/or deformations, which reduce their load capacity, and this in turn can cause accidents (Aliaga, 2019).

To ensure the proper performance and durability over the useful life of this infrastructure (Torres, 2019).

When analyzing the materials that are part of the bases or subbases of flexible pavements, sometimes they do not meet the properties required by the standard, especially regarding their grain size composition, plasticity, and strength (Meza, 2019).

For his research, comparison between soil stabilization with asphalt emulsion, and soil stabilization with asphalt and diesel to determine which stabilization provides higher bulk density and CBR support ratio (Quiroz, 2017).

They published the Architecture and Engineering Journal, titled “Granular Materials Treated with Asphalt Emulsion for Their Use in Bases or Subbases of Flexible Pavements,” in which they explain the characteristics of granular materials for the construction of flexible pavements in the city of Portoviejo in Ecuador and the behavior of asphalt emulsions with their advantages and applications with said granular material (Zambrano, 2019).

Soil stabilization for the purpose of shaping the structure of a flexible pavement stabilized with cement in the city of Juliaca. Soil stabilization for the planning and construction of pavements is conceptualized as an improvement of the subgrade, subbase, and base materials or aggregates, significantly increasing load-bearing capacity and strength while reducing volume changes during wetting and drying, and also decreasing its sensitivity to water (Flores, 2015).

The stabilization of base materials in pavements is a common process applied to increase the strength, stability, load-bearing capacity, and mechanical properties of the layer, which, if properly designed and built with sufficient thickness, prevents the subgrade from deforming excessively (Kamran & Hashemian, 2021).

This layer is located immediately below the surface course, and its function is to absorb most of the vertical stresses, so that its stiffness or resistance to deformation under repeated traffic loads corresponds to the intensity of heavy traffic (Tejada & Alonso, 2020).

The effectiveness and reliability of the comparative analysis depend on following the appropriate research design procedures, sufficiently conducting laboratory tests, and performing all necessary calculations.

METHODS

The type of research is experimental; therefore, the cause-and-effect relationship predominates. The independent variable is the one that is manipulated (cause), which would be the aggregates with type I Portland cement and asphalt emulsions in the pavement. The dependent variable is the one being investigated (effect), improved mechanical properties through stabilizers. Additionally, samples from the Yocar quarry are used as material for the granular base of the pavement, in order to vary their physical and chemical properties and use type I Portland cement and asphalt emulsion stabilizers, obtaining the results from laboratory tests to validate the research.

Quantitative Approach

Due to the environment in which the research is conducted: it is developed in the field of geotechnics in order to address the mechanical properties of the Yocar quarry, which will be used for the granular base of the pavement, in case they do not meet the specifications of the Peruvian Technical Standards, improvement will be carried out with stabilization processes using type I Portland cement and asphalt emulsions, whose results will be used as conveniently as possible. This entire procedure will be carried out in the soil mechanics laboratory tests.

Explanatory Level

The purpose of this explanatory research is to establish, through the testing of hypotheses and interpretations, the final conclusions based on the results obtained in the soil laboratory using additives with Portland cement type I and asphalt emulsions, with the aim of taking advantage of chemical agents in a granular base of the pavement in Jr. the Jazmines in the Santa Celedonia Urbanization of the City of Juliaca.

Applied Type

Through data collection and laboratory tests, we were able to learn the results of the stabilizers with Portland cement type I and the asphalt emulsion stabilizers on the granular base of the pavement in Jr. the Jazmines of the Santa Celedonia Urbanization in the City of Juliaca. These results are applicable because they will help expand the knowledge of the professionals involved in the execution of the pavement.

RESULTS

The laboratory tests were carried out following the procedures as indicated in the soils and pavements manual (MTC, 2018).

Responses from the tests carried out on the Granular Base of the pavement

The tests were carried out in the laboratory according to the procedures indicated in the established Peruvian standards. The following Table 1 shows the results at the ground level in the granular base of the pavement.

Table 1**Test Responses Developed on the Granular Base**

Test	Unit	Granular Base
Granulometry		
SUC		GP – GM
AASHTO		A-1-a
Moisture Content	%	6.3
Maximum Dry Density	gr/c3	2.292
CBR al 100% de la MDS	%	65.1

Source: Own elaboration.

Responses of Coarse Aggregates in the Granular Base of the Pavement

Laboratory tests of coarse aggregate were carried out in the granularity of the pavement base according to Peruvian standards. These responses are presented in Table 2.

Table 2**Specific Weights of the Granular Base**

Test	Unit	Granular Base
Dry Bulk Specific Weight (gr/cm3)	gr/cm3	2.7
Saturated Bulk Specific Weight (gr/cm3)	gr/cm3	2.72
Apparent Specific Weight (gr/cm3)	gr/cm3	2.755
Absorption	%	0.75

Source: Own elaboration

Responses of the tests on Fine Aggregate in the Granular Base of the Pavement.

These laboratory tests of the fine aggregate were conducted in the granular subbase of the pavement according to the procedures indicated in Peruvian standards. These responses are presented in Table 3.

Table 3

Test Responses Conducted on the Fine Aggregate of the Granular Base

Test	Unit	Granular Base
L.L.	%	22.0
L.P.	%	18.4
I.P.	%	3.6
E.A.	%	45

Source: Own elaboration.

Characteristics of Stabilizing Agents

Portland Cement Type I

Portland cement is one of the most widely used agents in the world for soil stabilization; it has the advantage that when the cement hydrates, the mixture transforms into a hard and rigid material (Vladimir, 2016). Therefore, Portland Cement Type I was used as a stabilizer for granular mixtures due to its high strength, a requirement according to the standard (NTP, 2013).

Stabilization with Portland cement increases its mechanical strength properties, plasticity, and is stable under the weather conditions to which the pavement is exposed (Vladimir, 2016).

Cationic Asphalt Emulsions

The asphalt emulsion is composed of three basic ingredients: asphalt, water, and an emulsifying agent (ASSOCIATION USA, 1999). It is a product obtained by dispersing the bituminous phase in another aqueous phase in which the particles are charged. In this case, the liquid that forms it is a discontinuous phase, and water is a continuous phase. The properties largely depend on the chemicals used as emulsifier (Meza, 2019; Piusseaut, 2020; Infante, 2006). According to the asphalt emulsion manual, it shows some of its characteristics (Sánchez & Lazo, 2019).

To establish the appropriate volume of emulsion to use, an initial theoretical emulsion value is required; this value represents the average of values obtained from an equation proposed at the University of Illinois – USA, "Illinois Proposed Methodology for Cold Mix Emulsion – Aggregate Design." In the design stage, a coating test is carried out in which a minimum amount of cement is added, ranging from $0.3\% \leq x \leq 1\%$, since cement has hydraulic properties that provide wet stability strength. Variable percentages of emulsion are taken in relation to the residual asphalt, as it is this that remains in the stabilized soil (according to standard requirements). After preparing the mixture, the final dry unit weight is obtained.

The same procedure is repeated until a relationship between the Dry Unit Weight and the Emulsion Content is obtained. The same procedure is repeated until a relationship between the Dry Unit Weight and the Emulsion Content is obtained. In the compaction curve, the appropriate values of emulsion content and maximum modified dry unit weight are determined (Aliaga & Soriano, 2019).

Responses with Portland cement and asphalt emulsion stabilizers in the Granular Base of the Pavement.

A summary table is shown where the stabilizers are applied to the soil, including type I Portland cement and asphalt emulsions, as shown in Table 4.

Table 4

Results obtained with Portland cement and asphalt emulsion stabilizers.

Test	Unit	Granular Base		
		Natural floor	Soil – Portland Cement (5%)	Soil – Asphalt Emulsion (5.8%)
Optimal Moisture Content	%	6.3	7.1	5.8
Maximum Density Dry	Gr/cm3	2.292	2.303	2.281
CBR at 95% of the MDS	%	48.3	126.0	58.2
CBR at 100% of the MDS	%	65.1	153.5	75.3

Source: Own elaboration.

Study and commentary of results

Material from the YOCARÁ quarry was used to create the granular base, resulting from the particle size analysis in the soil laboratory, which was conducted using the Unified Soil Classification System (USCS) methodology, resulting in Gravel with Limestone and Sand (GP GM), which requires performing a California Bearing Ratio (CBR) test. This laboratory test yielded a value of 65.10 percent, so further stabilization is needed to meet the minimum requirement of 80 percent established in the Road Manual for granular base materials.

In the test carried out on the fine soils of the granular base, the Plasticity Index was 3.6 percent, which means a slight increase in the soil's moisture content makes

it go from a semi-solid state to a liquid state, that is, it is extremely sensitive to variations in moisture content.

The tests carried out on the fine aggregates reveal a Liquid Limit of 22 percent and a Plasticity Index of 3.6 percent for the material used in the granular base of the pavement; this meets the requirements to use type I Portland cement stabilization by complying with the following parameters: Liquid Limit equal to 40 percent and Plasticity Index equal to 18 percent.

The results of the Californian Bearing Ratio (CBR) test at 100 percent of the Maximum Dry Density (MDD) of the sample plus Portland cement (Dosage: at 5 percent) were 152.4 percent, which is within the minimum parameters of the Peruvian regulations for granular pavement bases.

The tests carried out on the fine aggregates showed that the sample for the supposed pavement base had a Liquid Limit of 22 percent and a Plasticity Index of 3.6 percent, meeting the requirements for the use of stabilization with asphalt emulsions: Liquid Limit less than 30 percent and Plasticity Index less than 10 percent.

The results of the California Bearing Ratio (CBR) at one hundred percent of the Maximum Dry Density (MDD) plus the asphalt emulsion (Dosage: 5.80 percent) was 75.3 percent, therefore, it does not meet the minimum requirements established by the Peruvian standard.

CONCLUSIONS

This research was carried out according to Peruvian technical standards to carry out the structural design of the pavement of Jr. the Jazmines in the Santa Celedonia Urbanization in the city of Juliaca. The results were obtained through the soil laboratory; the sample used for the granular foundation of the pavement was prepared with and without stabilizers. All the results were analyzed in order to draw significant conclusions about the advantages of pavement stabilization based on Portland cement type I and based on asphalt emulsion.

Secondly, the following parameters are obtained after performing a granulometry test with the material that will be used in the granular base of the pavement: Sample A-1-a has the following properties: Liquid Limit equal to 22 percent, Plastic Limit equal to 18 percent, and Plasticity Index equal to 3.6 percent.

In order to apply Type I Portland cement for the stabilization of the granular base of the pavement, it must meet the following specifications: A-1, A-2, A-3, Liquid Limit equal to 40 percent, and Plasticity Index equal to 18 percent.

These results of the granular base of the pavement meet the usage conditions for stabilizers with asphalt emulsions, with a Liquid Limit less than 30 percent and a Plasticity Index less than 10 percent.

When verifying the appropriate dose of Type I Portland cement for stabilization, the Manual for the Construction of Stabilized Bases from the American Concrete Institute (ACI) was used, as well as the Geotechnical Aspects Manual for Highway Construction from the Federal Highway Administration (FHWA).

In addition, the dose of Portland cement ranges between 3 and 5 percent, depending on the type of granular material classified by the Unified Soil Classification System and the American Association of State Highway and Transportation Officials (AASHTO). Using a 5 percent Portland cement content as an example. For the modified Proctor test, we will use water concentrations of 4 percent, 6 percent, and 8 percent.

It is concluded that according to the Manual of Soils, Geology, Geotechnics, and Pavements MTC, (2018) and the American Concrete Institute manual ACI, (2009).

Furthermore, it uses the retained percentages obtained from the granulometry analysis to perform the calculations of the aforementioned methods. Assuming an average of the two methods, a result percentage of 5.05 percent is obtained for the optimal water content of the emulsion, which is consistent with the results of the different methods. Therefore, emulsion concentrations of 3 percent, 5 percent, and 7 percent with additional water were used in the modified Proctor test.

The results of the Californian Bearing Ratio (CBR) for the moisture contents for each stabilizer at 100 percent with maximum dry density are as follows: 65.1 percent is a Natural Soil; at 75.3 percent it is a Sample with Emulsions.

The use of stabilization with Type I Portland cement considerably increases the resistance of the pavement.

For the structural design, we show the results that were calculated based on the different methods. These results demonstrate that the AASHTO methodology is more expensive when using the sample without stabilizers and with asphalt emulsions, but less expensive when using Portland cement type I emulsions for stabilization, with the price difference ranging between 16,000.00 and 30,000.00 soles compared to the NASSRA method and 2,600 soles in the latter case. It should be noted that these prices are per paved kilometer. Asphalt (Dosage: 5.8 percent), and 153.5 percent for the Portland Cement Sample (Dosage: 5 percent). Based on the data, we can say that the mixture of materials with Portland cement type I has the best California Bearing Ratio (CBR) characteristics.

To determine the pavement depths, the low-volume road design methods of AASHTO 1993 and NAASRA were used, obtaining with the AASHTO method depths of 38 centimeters for unmodified materials and depths of 28 centimeters for stabilized materials. And using the NAASRA method, we obtain an extension of approximately 30 centimeters.

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INFLUENCE OF THE INOCULUM-SUBSTRATE RATIO ON THE BIOCHEMICAL METHANE POTENTIAL OF WHEY

Quispe Flores, Leonela

ABSTRACT

Whey is one of the most characteristic waste products of the cheese industry, with a high organic matter content. Therefore, the objective of this study was to evaluate the influence of the inoculum-substrate ratio on the biochemical methane potential of whey waste from a cheese plant. Two types of whey, salted and unsalted, were analyzed using anaerobic digestion under mesophilic conditions in batch reactors with different inoculum-substrate ratios (2, 2.5, 3, 3.5, 4, and 5) and a control reactor. The cumulative biochemical potential of salted and unsalted whey yielded the highest values at the inoculum-substrate ratio of 2, with values of 0.058 and 0.066 L CH₄/g VS, respectively. A difference was observed between the inoculum-substrate ratios. In other words, the best treatment was the inoculum-substrate ratio of 2, due to the action of the microorganisms. Higher substrate concentrations resulted in better performance, with a significance level of 95%.

Keywords: Inoculum-substrate relationship, whey, biochemical methane potential.

INTRODUCTION

In Latin America, milk production is 81.3 million tons (FEPALE, 2019), and according to the OECD/FAO (2015), global milk production is projected to increase to 175 million tons by 2024. In Peru, milk production is 2,135,881 tons per year (MIDAGRI, 2020), and the Puno region produces more than 200,000 liters of milk daily. Over 80% of this production is concentrated in the provinces of Melgar, Azángaro, Puno, and Huancané (MINAGRI, 2019). Consequently, whey production is highest in these provinces. Uncontrolled whey dumping can cause environmental pollution problems due to the high concentration of nutrients that promote bacterial growth (Macedo et al., 2018; Tribst et al., 2020). It also alters soil structure (Araujo et al., 2013). Pure whey is used for animal feed, while salted whey is dumped into rivers or onto the ground (Bansal & Bhandari, 2016).

Milk is composed of 90% water and approximately 85-95% of its volume is made up of lactose, proteins, fats, and minerals. It also contains substances such as pigments, enzymes, vitamins, and phospholipids (Kavacik & Topaloglu, 2010). Therefore, cheesemaking concentrates the casein and fat through coagulation, forming a gel that curdles and separates into whey (Trujillo & Zapana, 2020). Whey contains proteins and minerals (Giroux et al., 2018) and has a high organic matter content (Fernández et al., 2016). There are two types of whey; Pure whey has a pH of 5.2 – 6.7 and salted whey maintains a pH <5.0, therefore, they differ due to the action of lactic acid bacteria and the addition of sodium chloride, they are similar in proteins, lactose, ash and minerals (Lievore et al., 2015; Giroux et al., 2018).

Anaerobic digestion (AD) is an ideal technology for whey treatment, due to the action of different bacterial populations that generate methane and carbon dioxide (Capcha, 2014), with 4 stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis (Fernández et al., 2016). In this process, they are grouped into two parts; first, the producers of volatile fatty acids (VFAs) (hydrolysis and acidogenesis) involve most of the microbial diversity, and the second is composed of the consumers of VFAs (acetogenesis and methanogenesis) (Liu, 1997), which generate hydrogen and methanogenesis transforms simple compounds such as methane (CH₄), carbon dioxide (CO₂) (Jonge et al., 2020; Ali shah et al., 2017). Similarly, the biochemical methane potential test is used to quickly assess whether the residue can be degraded to produce CH₄ (Sánchez et al., 2016). Furthermore, it is characterized by its simplicity, speed, and low cost. Methane production is also measured using the manometric method (Cárdenas et al., 2016). Therefore, the inoculum-substrate ratio is a way to evaluate the capacity of the whey residue. This is because the stability of anaerobic digestion is reflected in pH parameters within a range of 6.5 to 8 (Poh & Chong, 2009), and the buffering capacity, expressed as the VFA/TA ratio, should be below 0.4 (Kong et al., 2016).

The inoculum-substrate ratio is a factor that influences the PBM assay, which is expressed as a function of the volatile solids (VS) content of the inoculum and substrate. Raposo et al. (2009) conducted a study of sunflower oil at RIS values of 3, 2, 1.5, 1, 0.8, and 0.5, obtaining results of 0.38 and 0.44 mL/g at RIS values of 1 and 2, respectively. Similarly, Thanarasu et al. (2019) evaluated lignocellulose biomass at RIS values of 2.5 and 5, with the highest methane yield being 587.3 mL/g at RIS value of 2.5. Mahat et al. (2020) developed their study of food processing wastewater with high oil and fat content at RIS values of 1, 1.5, and 2, with the maximum biogas production being 228.6 mL/g. An RIS of 1 was considered optimal, as it also achieved high removal rates for other parameters (COD and BOD). Studies of the anaerobic digestion of whey residue yielded methane values of 400 and 200 mL at RIS of 2 and 4, respectively, due to their

VFA/TA stability conditions (Barrena et al., 2017). Guerrero et al. (2016) reported that salted and pure whey produced an average methane yield of 300 and 430 L CH₄/Kg per day, respectively, at an RIS of 2, which was considered optimal. Jaimes et al. (2020) conducted a whey study, achieving a production of 300 and 590 L CH₄/Kg VS at 35 °C at an RIS of 2, demonstrating the best ratio compared to the other RIS values evaluated.

The inoculum-substrate ratio is a factor that can influence anaerobic digestion; therefore, it is based on the volatile solids (VS) of the inoculum and substrate (Raposo et al., 2009). The percentages for RIS 2, 2.5, 3, 3.5, 4, and 5 are (50:50, 60:40, 67:40, 71:40, 75:25, 80:20%), respectively. Studies of the anaerobic digestion of whey residue obtained methane values of 400 and 200 mL from whey (2% and 4%) due to its VFA/TA stability conditions (Barrena et al., 2017). Guerrero et al. (2016) mention that salted and pure whey obtained an average methane production of 0.30 and 0.43 m³ CH₄/Kg per day, respectively. Jaimes et al. (2020) in the RIS 2 reached a production of 0.30 and 0.59 m³ CH₄/Kg SV at a temperature of 35 °C, showing the best ratio.

METHODOLOGY

Substrate and inóculum

The substrate was pure, salted whey, collected from a cheese factory in the province of Melgar, Puno, Peru. Samples were transported in 1-liter containers and refrigerated at 4 °C until analysis. Inoculum was applied using sludge samples from the anaerobic digester (recirculating from the secondary treatment of a wastewater treatment plant located in the department of Cusco). This sludge had been stored at 30 °C for 7 days prior to application (Holliger et al., 2016). The following parameters were characterized: volatile sulfur (VS), volatile fatty acids (VFA), total fatty acids (TF), chemical oxygen demand (COD), and pH. The results are presented in Table 1.

Table 1

Physicochemical characterization of the whey substrate and inoculum

Parameters	LS. P	LS. S	Inóculo	Units
SV	53.70 ±0.9	29.75 ±0.2	16.35 ±1.2	g/kg
AGV	2600 ±34.6	1900 ±34.6	2060 ±69.3	mg/L
AT	2083 ±28.9	1517 ±57.7	3717 ±115.5	mg/L
DQO	1044.75 ±14.16	607.25 ±23.2	1020.58 ±22.5	mg/L
pH	6.62 ±0.1	6.4 ±0.1	7.6 ±0.1	--

*LS.P: Pure whey

**LS.S: Salted whey

Inoculum-substrate relationship

Table 2 shows the setup in batch reactors at different RIS, according to the percentages of the inoculum-substrate ratio, all based on the volatile solids of the inoculum 17.00 g/kg VS (A. Parra et al., 2015), also of both substrates, pure whey 53.70 g/kg VS and salted whey 29.75 g/kg VS. 39 experimental units were developed, at an RIS of (2, 2.5, 3, 3.5, 4, 5), and their respective blank, under mesophilic conditions 35 °C.

Table 2

Batch reactor assembly

Reactores batch	Volume		Ratios (%)
	LS. P (g SV/kg)	LS. S (g SV/kg)	
2	9.50	17.14	50:50
2.5	7.60	13.71	60:40
3	6.33	11.43	67:33
3.5	5.43	9.80	71:29
4	4.75	8.57	75:25
5	3.80	6.86	80:20

Determinación del potencial bioquímico de metano

The biochemical potential assays of methane were developed according to the protocol established by Holliger et al., (2016), in triplicate in batch reactors, 120 mL glass bottles with a working volume of 60 mL, then gassed with nitrogen gas for 30 seconds, closed with rubber bv septa and sealed with aluminum clamps.

The methane produced was quantified daily using the gas density method, where the initial mass of the reactor was weighed and the volume of biogas was measured in a manometer with its syringe, then the final mass of the reactor was weighed, developed (Justesen et al, 2019).

Equation (1) is the density of biogas at standard conditions, where Pb is density; Δmb is mass loss from the bottle; Vb is standardized biogas volumen.

$$pb = \frac{\Delta mb}{v_b} - CH_2O \quad (1)$$

Analytical methods

The parameters Volatile Solids (VS), Total Solids (TS), and Chemical Oxygen Demand (COD) were analyzed according to standardized methods (American Public Health Association, 2017). pH was measured using a benchtop potentiometer. Volatile Fatty Acids (VFAs) and Total Alkalinity (TA) were analyzed using titration. All tests were performed at the beginning and end of methane production at different RIS values (2, 2.5, 3, 3.5, 4, and 5) and on the inoculum, which served as the blank.

Statistical analysis

The experiments employed a 2x7 factorial design, with the first factor being whey type and the second factor being the RIS (Resistance Index) with 7 levels and 3 treatments (replicates), for a total of 39 experimental units. ANOVA and Tukey's test were performed for the RIS, and a t-test was used for the whey type at a 95% confidence level. Data were analyzed using SPSS statistical software, and the Gompertz model was determined using Statgraphics software.

Kinetic model

The biogas generation kinetics were fitted to the modified Gompertz model for the analysis of biogas production in the anaerobic digestion process according to each RIS. Likewise, the modified Gompertz model is a nonlinear sigmoidal fit (Rodrigues et al., 2021) with greater application (Thanarasu et al., 2019) for a first-order steady-state process kinetics (equation 2). Thus, the coefficient of determination (r^2) is considered good when it is close to 1.

$$B = B_o \cdot \exp \left\{ -\exp \left[\frac{R_{max} \cdot e}{B_o} (\lambda - t) + 1 \right] \right\} \quad (2)$$

Where B is biogas production (mL CH₄/g); B_o is the maximum biogas production (mL CH₄/g); R_{max} is the maximum biogas production rate (mL CH₄/g); λ is the lag phase (d); t is the digestion time (d); e is equal to 2.718 (B. A. Parra et al., 2019; Bedoi et al., 2020).

RESULTS AND DISCUSSION

Potencial bioquímico de metano

Figure 1 shows the cumulative PBM results for 8 days of salted and unsalted whey. During the first 4 days, methane production was similar for all RIS samples; however, RIS 2 had the highest production, with values of 0.058 and 0.066 L CH₄/g VS, after which it stabilized. This indicates that there was easily degradable organic

matter present during the first few days. Jaimes et al. (2020) obtained between 300 and 590 L CH₄/g VS, while Escalante et al. (2017) obtained 469.2 L CH₄/g daily, which definitely shows better performance in their study with whey. Its capacity may be improved with treatment. The imbalance of anaerobic digestion induced vulnerable hydrolysis, consequently reducing methane production during the methanogenesis stage. There is a significant difference among the RIS samples ($P < 0.05$ in the ANOVA).

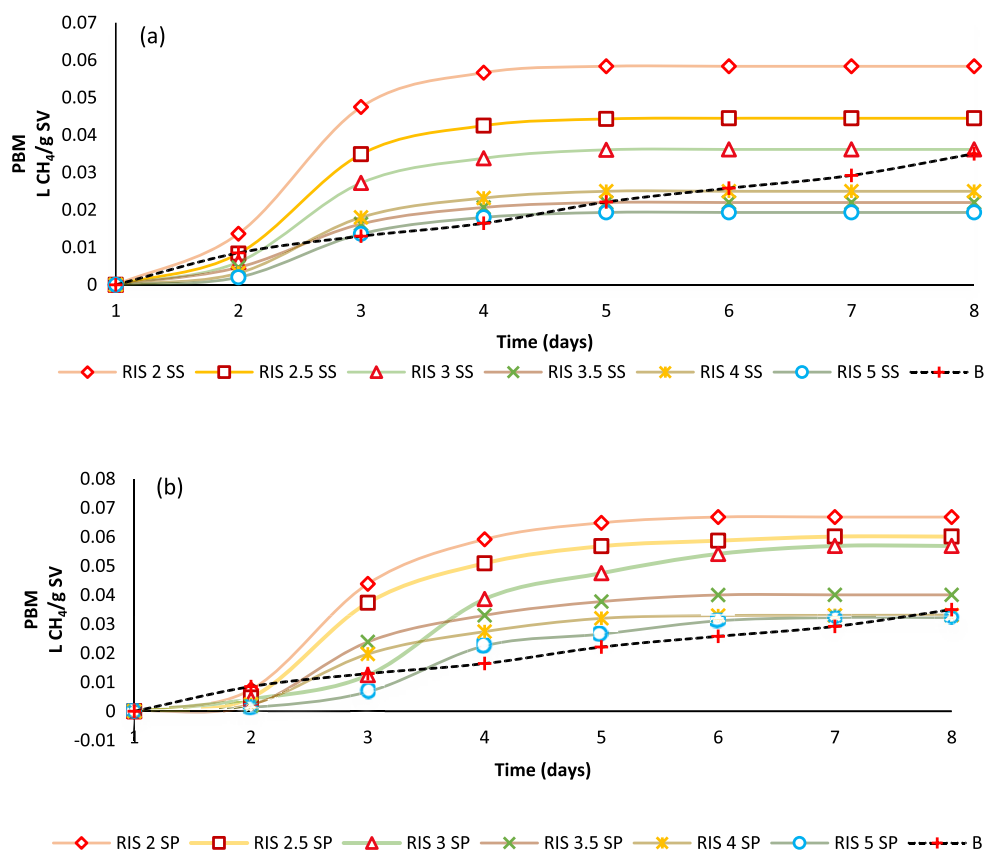


Figure 1

Cumulative PBM of salted and pure whey at different RIS over 8 days

Parameter evaluation

Sólidos Volátiles y sólidos totales

Table 2 shows that whey is a substrate with a high content of organic matter in the form of lactose and proteins. The degradation of macromolecules depends on the ratio between the acidogenic and methanogenic metabolic growth rates (Yang et al., 2015). Ultimately, the concentration decreased in both types of whey, although the highest VS (Vulture Sodium) was observed in pure whey. Both concentrations were less than 100 g/kg VS, as indicated by Holliger et al. (2016).

Table 3

SV concentration, ST of methane production

Treatment	SV (g/kg)		ST (g/kg)	
	initial	finish	initial	finish
RIS 2 SS	15	9	36	29
RIS 2.5 SS	13	9	32	27
RIS 3 SS	14	9	31	25
RIS 3.5 SS	14	10	32	27
RIS 4 SS	13	11	29	28
RIS 5 SS	13	11	28	26
RIS 2 SP	16	11	27	21
RIS 2.5 SP	15	12	25	23
RIS 3 SP	16	12	27	22
RIS 3.5 SP	15	11	26	21
RIS 4 SP	13	11	23	22
RIS 5 SP	13	9	23	18

Hydrogen Potential (pH)

Figure 2 shows the pH behavior of both types of whey. The final pH values for the salted whey were between 7.8 and 8.3, decreasing considerably, while the pure whey maintained a pH between 7.6 and 7.8, close to the initial values, demonstrating the action of the microorganisms. Likewise, the optimum pH was found in a range of 6.8–7.3 (Thanarasu et al., 2019) and 7–8 (Raposo et al., 2020).

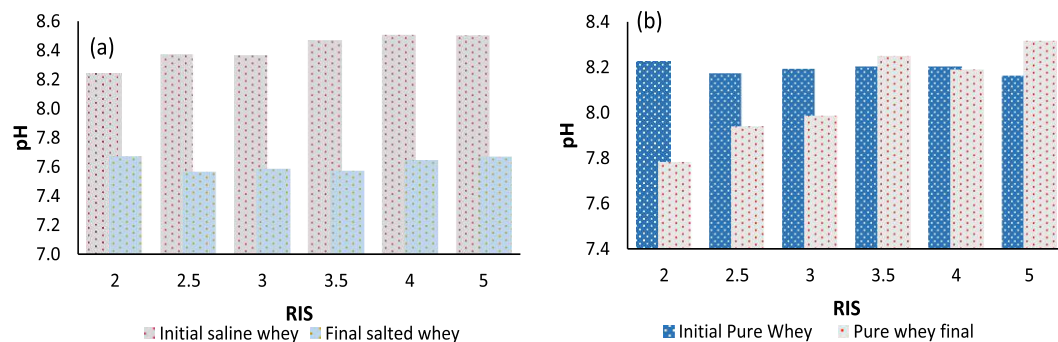


Figure 2

pH concentration of salted and pure whey in biogas production

Volatile fatty acids (AGV)

Figure 3 shows that pure whey predominates in most of the RIS samples. This substrate, with a pH of 7.8–8.3, tends to acidify, as the volatile fatty acid (VFA) content increased at the end. Specifically, RIS samples 2 of both whey samples exceeded 5,000 mg/L, which Xu et al. (2014) indicated as inhibitory.

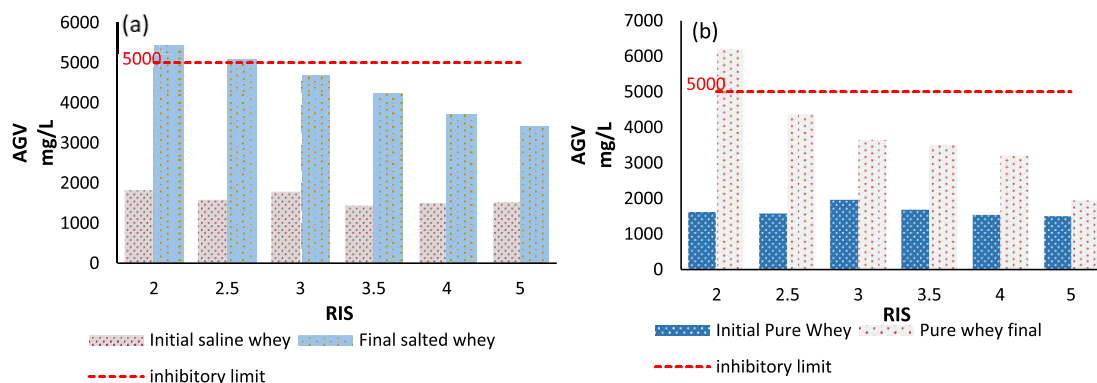


Figure 3

VFA concentration of salted and pure whey in biogas production.

Stability of anaerobic digestion

Figure 4 shows that pure whey predominates in the RIS (Reactive Saturations), with stability achieved through buffering capacity (VFA/TA) and pH. All RIS samples from both wheys exceeded the 0.4 mg/L threshold indicated by Kong et al. (2016), tending to acidify due to the high concentration of VFAs and the lack of TA. Similarly, Escalante et al. (2017) indicate that whey is an acidic substrate. This is because the microorganisms are not in optimal conditions, particularly with acidic whey (Guerrero et al., 2016).

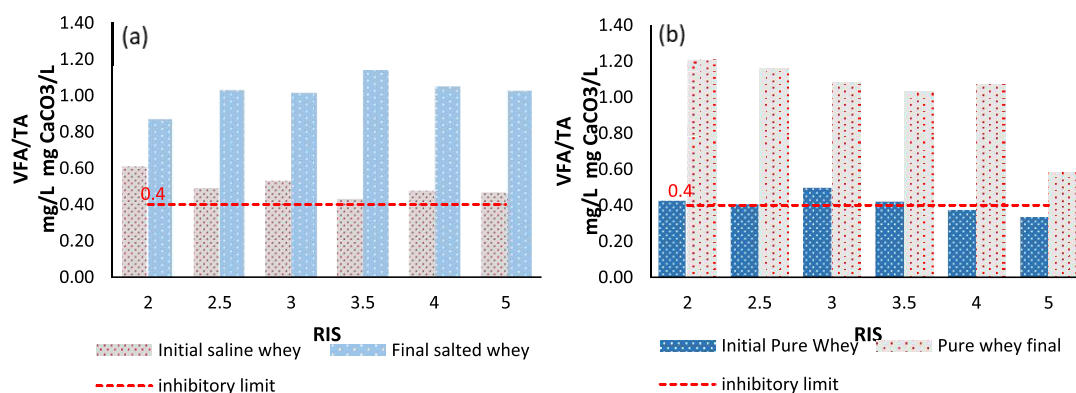


Figure 4

Concentration of the buffering capacity of salted and pure whey

Kinetic evaluation

Figure 5 shows the modeling results, using the modified Gompertz equation, for all RIS values of both whey samples. The results show a high degree of similarity between the model simulation and the experimental data, indicating that the highest Bo values are 58.42 and 66.53 mL/g, obtained from the RIS of 2 for salted and pure whey, with R² values of 100% and 99.92%, respectively. This model accurately predicts the behavior in batch reactors and represents the activity of microorganisms in anaerobic digestion (Raposo et al., 2009). Furthermore, it predicts that biogas production is directly proportional to the growth rate (Thanarasu et al., 2019).

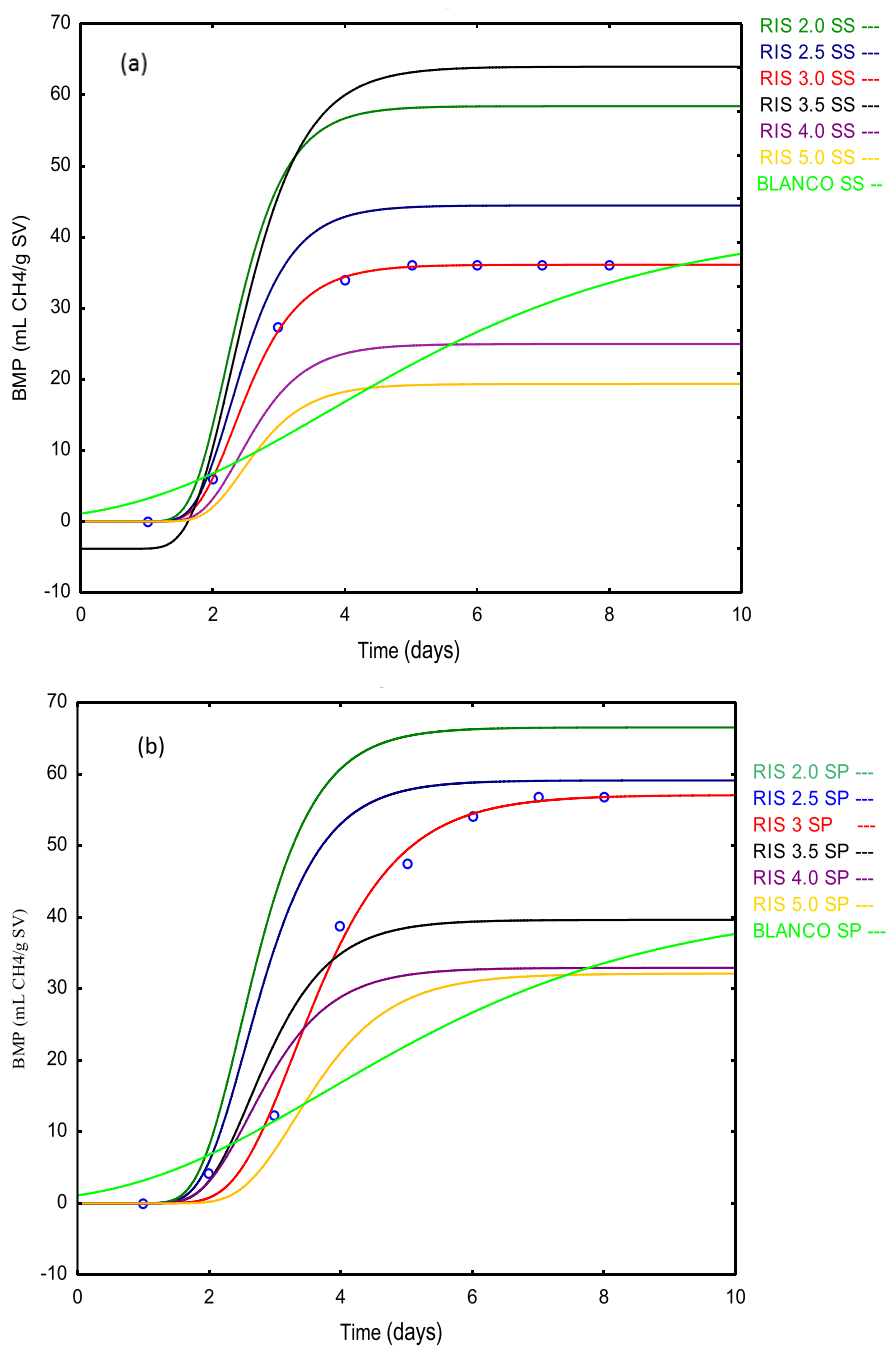


Figure 5

Modified Gompertz model based on experimental data (a) salted whey and (b) pure whey

CONCLUSIONS

Whey is a liquid residue used for biogas production through anaerobic digestion. The accumulated biomass production (BMP) of salted and pure whey from the RIS of 2 is 0.058 and 0.066 L CH₄/g VS, respectively, with the highest production occurring in the salted and pure whey. This indicates that the inoculum-substrate ratio does influence both types of whey. Experiments show that whey is an acidic substrate that tends to be inhibited when volatile fatty acids (VFAs) exceed 5000 mg/L. Even the VFA/TA buffering capacity exceeding 0.4 acidified the whey, demonstrating its instability in anaerobic digestion. Further studies at an RIS of 2 should be conducted.

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INFLUENCE OF CATIONIC SURFACTANT NANOCOMPOSITES IN SOIL-CEMENT MIXTURES FOR BASE COURSES, WITH MATERIAL FROM THE HUATA QUARRY, 2024

Ramos Medina, Dennis Marwin

ABSTRACT

This research focuses on the need to find alternatives to improve the physical and mechanical properties of the soils used in roads in the Puno region, which are predominantly clayey. The use of plant-based cationic surfactant nanocomposites (polymers) applied to soil-cement bases is proposed in order to improve the strength and durability of unpaved roads, an improvement that is reflected in the results of soil laboratory tests. The **objective** was to analyze the performance of material from the Huata quarry for soil-cement bases with the incorporation of cationic surfactant nanocomposites. The **methodology** was based on basic research, with a quantitative approach, explanatory level, and experimental design, conducting laboratory tests on samples extracted from a quarry in Huata. The most relevant **results** are as follows: at a maximum dry density of $2,249 \text{ g/cm}^3$ with 0.5% cement and 0.05% nanocomposite, the 100% soil bearing capacity was between 413.6% and 454.5% with 1.55% cement and 0.03% to 0.1% nanocomposite, and the simple compressive strength was 35.3 kg/cm^2 with 2% cement and 0.03% nanocomposite. It is **concluded** that the incorporation of cationic surfactant nanocomposites in cement-stabilized soils for bases improves their resistance and durability to wear, making them an alternative for improving unpaved road infrastructure.

Keywords: Soil-cement bases, base performance, base stabilization, surfactant nanocomposites, polymers.

INTRODUCTION

In the construction of road works in Peru, and especially in the Puno region, soil stabilization and the quality of the bases are essential to ensure the durability and safety of the roads (Laricano & Reynaldo, 2021). The Puno region, located in the Peruvian highlands and mountains, faces particular difficulties associated with the presence of silty clay soils, which have low bearing capacity and are prone to

moisture retention (Guzmán, 2021). These soil conditions result in unpaved roads with poor resistance, increasing maintenance and repair costs.

The district of Huata, in the Puno region, has departmental and rural roads with a high clay and silt content, which suffer accelerated deterioration due to a combination of extreme weather and heavy traffic (Regional Government of Puno, 2015). The lack of soil stability leads to deformations and potholes that worsen the quality of road service, which affects the safety and comfort of users, in addition to limiting the socioeconomic development of the area.

METHODOLOGY

The research is basic in nature, as it is aimed at increasing theoretical scientific knowledge to improve processes and products for application in various real contexts, although it was decided to use materials from a quarry in Huata, which served as a control group (Vara, 2015).

The approach is quantitative, as numerical data are collected to test hypotheses and explain measurable phenomena. According to Hernández et al. (2010), this approach "uses data collection to test hypotheses, based on numerical measurement and statistical analysis, to establish patterns of behavior and test theories".

An explanatory level of research is adopted, since the aim is to determine the causes or influence of the independent variables (addition of nanocomposites) on the dependent variables (performance of soil-cement bases).

The present study adopts an experimental design, since the independent variable (addition of different percentages of cationic surfactant nanocomposites) is deliberately manipulated to observe its effect on the performance of soil-cement bases (dependent variable).

RESULTS

This research paper presents the data and results obtained from the analysis and evaluation of the information collected during the research process.

Laboratory tests were carried out to characterize the material to be used in soil-cement bases. The results obtained are shown below:

Table 1

Physical and mechanical tests performed

Test performed	Standard (MTC)	Internal code	Test date	Result	Reference Value EG-2013 *	Compliance
Granulométric Analysis	MTC E 107	AG-1	17-19/06/24	G=42.51%; A=42.74%; F=15%	Type A gradation	Does not comply
Natural moisture content	MTC E 108	CH-1	07-08/08/24	3.44%	Not specified	-
Liquid limit (LL)	MTC E 110	LL-1	18-19/06/24	LL=25%	-	-
Plastic limit (LP)	MTC E 111	LP-1	18-19/06/24	LP=16.3%; IP=8.7%	IP 2% mín.	Complies
Sand equivalent	MTC E 114	EA-1	10-11/09/24	25%	45% mín.	Does not comply
Los Angeles abrasion	MTC E 207	AA-1	11-13/09/24	25.90%	40% máx.	Complies
Flat and elongated particles	MTC E 223	CHA-1	11-12/09/24	3.30%	15% máx.	Complies
Fractured particles (one side)	MTC E 210	PF-1	11-12/09/24	19.99%	80% mín.	Does not comply
Fractured particles (≥ 2 faces)	MTC E 210	PF-1	11-12/09/24	6.22%	50% mín.	Does not comply
Soluble salt content	MTC E 219	SS-1	23-30/09/24	<0.001%	0.5% máx.	Complies

Note: (G=Gravel; A=Sand; F=Fines; IP=Plasticity Index). (*) ≥ 3000 m.a.s.l. MTC (Ministry of Transport and Communications).

The material analyzed has physical and mechanical conditions that are partially suitable for use in cement-stabilized bases. Noteworthy positive features include abrasion resistance (25.9%), adequate particle morphology (only 3.3% of flat and elongated particles) and low soluble salt content (<0.001%), which are favorable conditions for chemical stabilization.

However, the deficiencies observed in the granulometry (type B gradation instead of type A), sand equivalent (25% compared to the minimum requirement of 45%) and, above all, angularity (insufficient fractured particles) pose significant technical limitations, requiring additional improvements through the use of binders and additives.

Laboratory tests are carried out to find the maximum dry density at different proportions of cement and cationic surfactant nanocomposites. The results obtained are shown below:

Table 2

Density analysis

ÍTEM	CEMENT (%)	ADDITIVE (%)	Maximum dry density (gr/cm ³)
1	0.00	0.00	2.215
2	0.50	0.00	2.194
3	1.00	0.00	2.219
4	1.50	0.00	2.204
5	2.00	0.00	2.220
6	0.00	0.03	2.212
7	0.50	0.03	2.246
8	1.00	0.03	2.213
9	1.50	0.03	2.232
10	2.00	0.03	2.211
11	0.50	0.01	2.241
12	0.50	0.02	2.241
13	0.50	0.05	2.249
14	0.50	0.07	2.230
15	0.50	0.10	2.246

Note: Own elaboration.

Table 2 shows that the maximum dry density of the soil-cement-nanocomposite samples ranges from 2.211 to 2.249 g/cm³, the maximum dry density of the soil-cement samples is in the range of 2.194 to 2.220 g/cm³, and the standard sample has a maximum dry density of 2.215 g/cm³. From these results, it is determined that the maximum dry density of the soil-cement samples can be improved by up to 0.22% compared to the standard sample, and the maximum dry density of the soil-cement-nanocomposite samples can be improved by up to 1.5% compared to the standard sample.

Laboratory tests are carried out to find the support ratio value at different proportions of cement and cationic surfactant nanocomposites. The results obtained are shown below:

Table 3

CBR results

Description			CBR 0.1" (%)	CBR 0.1" (%)
Item	Cement (%)	Additive (%)	95%	100 %
1	0.00	0.00	29.40%	49.50%
2	2.00	0.00	305.20%	464.70%
3	1.50	0.00	232.40%	482.50%
4	1.50	0.03	228.40%	433.90%
5	1.50	0.05	218.40%	454.50%
6	1.50	0.07	141.50%	430.50%
7	1.50	0.10	150.20%	413.60%
8	2.00	0.03	242.40%	440.70%

Note: Own elaboration. CBR (California Bearing Ratio)

The results of the soil bearing capacity show notable increases in the bearing capacity of the treated soil, particularly when cement dosages of 1.5% to 2.0% are used, reaching values greater than 400% of the bearing capacity of soils at 100% of maximum dry density.

Laboratory tests are carried out to determine the simple compressive strength at different proportions of cationic surfactant nanocomposites. The results obtained are shown below:

Table 4

Compressive strength

Especimen code	% cement by weight	% additive by weight	Strength (Kg/cm2)	Average per group (Kg/cm2)	Average per group (Mpa)
1A	0.5	0.03	4.8	3.83	0.38
2A	0.5	0.03	3.8		
3A	0.5	0.03	2.9		
4B	2	0	14.9	18.40	1.81
5B	2	0	17.7		
6B	2	0	22.6		
7C	0	0	11.1	11.17	1.10
8C	0	0	11.4		
9C	0	0	11		
10D	1	0.03	12.9	13.57	1.33
11D	1	0.03	14		
12D	1	0.03	13.8		
13E	1.5	0.03	25.5	25.53	2.50
14E	1.5	0.03	25.5		
15E	1.5	0.03	25.6		
16F	2	0.03	29.1	31.40	3.08
17F	2	0.03	29.8		
18F	2	0.03	35.3		

Note: Own elaboration.

Table 4 shows that the simple compressive strength of the soil-cement-nanocomposite samples ranges from 2.90 to 35.30 kg/cm², the simple compressive strength of the soil-cement samples is in the range of 14.90 to 22.60 kg/cm², and the simple compressive strength of the standard sample varies in the range of 11.00 to 11.40 kg/cm². It is therefore determined that the simple compressive strength of the soil-cement-nanocomposite samples improves on average by up to 181.11% compared to the standard sample. The simple compressive strength of the soil-cement samples improves on average by up to 64.72% compared to the standard sample. In addition, the simple compressive strength of the soil-cement-nanocomposite samples improved on average by up to 70.65% with respect to the

soil-cement samples (), demonstrating that the nanocomposite has a significant influence on improving compressive strength.

DISCUSSION

The initial characterization of the soil-cement base materials carried out in this research showed a particle size distribution with 42.51% gravel, 42.74% sand, and 14.75% fines, indicating limitations in complying with the type A gradation recommended by the EG-2013 standard for granular bases at altitudes above 3000 meters above sea level. This particle size distribution contrasts with the results presented by previous studies such as that of Villalba and Venegas (2022), who consider that this type of soil should be stabilized with the addition of an additive plus cement.

Likewise, the research revealed a Plasticity Index (PI) of 8.7%, meeting the minimum requirement ($PI \geq 2\%$), but identified deficiencies in other important aspects such as the Sand Equivalent (25%) and the proportion of fractured particles, with only 19.99% for one face and 6.22% for two or more faces, figures below the regulatory standards ($\geq 80\%$ and $\geq 50\%$, respectively). The AASHTO soil classification is A-2-4(0), which is similar to that found by Villalba and Venegas (2022) and Nesterenko (2018), where soils classified as A-2-4(0) and A-2-4(0) were found, respectively, which determine soil improvement through the use of additives and cement. In addition, the soil classification by the SUCS method is SC, which contrasts with García-Toro (2019), Mamani et al. (2023), and Porta (2023), where soils classified as Kaolin, SC, and SC were found, respectively, and the authors suggest improving clay soils by adding an additive to stabilize them.

From the modified Proctor compaction tests (MTC E 115). The experimental results showed a maximum dry density of 2,215 g/cm³ without additives, up to 2,249 g/cm³ using a combination of 0.5% cement and 0.05% additive, validated by a quadratic model with an R^2 of 0.504. This finding exceeds that of Pacheco (2023), who stabilized poorly graded clayey sand with sulfonated oil at a rate of up to 0.7 l/m³, obtaining maximum dry densities of less than 2,126 g/cm³. It also surpasses the findings of Castillo (2018), Nesterenko (2018), and Calizaya and Juchani (2023), who improved clay soils with the chemical additive PROES plus cement, polyacrylamide polymers, and bottom ash, respectively.

With regard to the bearing capacity test, notable increases were observed, reaching values above 400% with cement dosages between 1.5% and 2.0%. These results considerably exceed those found by Guzmán (2021), Castillo (2018), Calizaya and Juchani (2023), and Choquechambi and Huanca (2023), who stabilized low-plasticity clay soils with PET polymers, PROES chemical additive plus cement, bottom ash, and potato husk ash, respectively, demonstrating the

advantage of using cement-nanocomposite in terms of strength and structural stability. However, the nanocomposite alone did not show direct statistical relevance in soil bearing capacity, although it may indirectly contribute to other soil properties such as cohesion thanks to its cationic surfactant properties, which favor chemical attraction with clays, as demonstrated (Adlie & Nurul, 2020).

Compressive strength showed results well above the minimum value required by the MTC EG-2013 manual (1.8 MPa), reaching up to 3.5 MPa with optimal combinations of 2% cement and 0.03% additive. This performance slightly exceeds that found by Bosov and Valiev (2018) and Niroumand et al. (2023), who used silicate additives plus cement in clay soils and used nanocement as an additive to kelachay clay soil, respectively. In well-graded and poorly graded sands such as those tested by Condori (2023) with the addition of asphalt emulsion, this does not exceed the values found when using the additive plus cement. It far exceeds the results found by Ortiz and Guanín (2025) and Vilca (2024), where lime hydroxide was used as an additive in highly plastic inorganic clay soil and quinoa husk ash in loamy soil, respectively. It also far exceeds the results tested by Chamba (2021), where low-plasticity clay soil was stabilized with NLF and Solidry additives. This confirms the hypothesis that the addition of nanocomposites can significantly optimize the structural strength of soil-cement bases, enhancing mechanical synergies in the cement-additive interaction and improving the internal cohesion of the mixture.

CONCLUSIONS

It is concluded that the performance of soil-cement bases has been improved with the application of cationic surfactant nanocomposites in soils from the Huata quarry. The evidence obtained shows an improvement in maximum dry density of 2.5% when comparing the soil-cement sample vs. the soil-cement-nanocomposite sample. The results for soil bearing capacity show a 405% improvement in the standard sample compared to the soil-cement-nanocomposite sample. The results for simple compressive strength show a 181.11% improvement in the standard sample compared to the soil-cement-nanocomposite sample.

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GARLIC PASTE AS AN ECOLOGICAL ALTERNATIVE TO INDUCE BUDBREAK IN GRAPEVINE (*VITIS VINIFERA* L.) CV. ITALIA IN THE MOQUEGUA VALLEY

Rentería Ventura, Julio Alonso

ABSTRACT

Low winter chill accumulation in the Moquegua Valley limits the natural release of bud dormancy in grapevines, necessitating the use of synthetic agents to ensure uniform bud activation. This study aimed to evaluate the effect of garlic paste as an ecological alternative to induce budbreak in grapevine (*Vitis vinifera* L.) cv. Italia. The experiment was conducted under a randomized complete block design (RCBD) with three replications. Treatments consisted of undiluted garlic paste, a chemical control (5% hydrogen cyanamide), and an untreated control. Periodic phenological assessments were carried out between 15 and 35 days after pruning. Data were analyzed using analysis of variance (ANOVA), and mean comparisons were performed using Tukey's test ($P \leq 0.05$). Results showed that garlic paste significantly modified the phenological dynamics of the crop, advancing the onset and reducing the mean time to budbreak (13.03 and 26.77 days, respectively) compared to the control, with a statistically similar response to hydrogen cyanamide. In addition, budbreak percentage (67.11%) and relative efficiency (86.71%) were substantially higher than the control, indicating a high technical potential as an alternative to the chemical standard. It is concluded that garlic paste constitutes a viable ecological alternative to promote uniform budbreak in grapevine cv. Italia under conditions of winter chill deficiency in the Moquegua Valley.

Keywords: *Allium sativum* L., hydrogen cyanamide, bud dormancy, chilling requirement, budbreak inducer, sustainable viticulture.

INTRODUCTION

Grapevine (*Vitis vinifera* L.) is one of the most economically and historically important fruit crops worldwide, forming the basis of a major agroindustry oriented toward the production of table grapes, wine, and spirits, supported by more than 7.2 million hectares of vineyards that produce approximately 75 million tons annually

(International Organisation of Vine and Wine [OIV], 2024). However, in an increasingly competitive agricultural context, achieving the high standards of productivity and quality demanded by current markets requires overcoming significant climatic and physiological constraints that affect crop development.

One of the most critical processes is budbreak, as it determines the onset of the vegetative cycle and, consequently, the potential number of fertile shoots and clusters (Dokoozlian et al., 1995; Lavee & May, 1997). In temperate climates, bud activation depends on the accumulation of chilling hours, defined as exposure to effective temperatures between 0 and 7.2 °C during winter dormancy. For grapevine, a general requirement of 150 to 400 chilling hours is estimated, depending on the cultivar (Dokoozlian, 1999; Keller, 2015). When this requirement is not met, vineyards exhibit delayed, uneven, and incomplete budbreak, resulting in yield losses and increased management costs (Erez, 2000; Luedeling, 2012).

This situation is characteristic of tropical and subtropical regions, such as the warm valleys of Peru. In particular, in the Moquegua Valley, climatic conditions prevent the fulfillment of winter chilling requirements (Hatta & Tonietto, 2012). Under these conditions, grapevines are unable to naturally overcome dormancy, making the use of budbreak-inducing agents necessary to ensure the economic viability of the crop (Almanza et al., 2010).

Traditionally, hydrogen cyanamide has been used as a chemical budbreak inducer due to its effectiveness in compensating for chilling deficiency (Shulman et al., 1983; Dokoozlian et al., 1995). This compound inhibits catalase activity, leading to the accumulation of hydrogen peroxide (H₂O₂) in plant tissues. The resulting oxidative stress acts as a biochemical signal that reactivates cellular metabolism and induces dormancy release in buds (Pérez & Lira, 2005). However, its use presents several limitations, including risks to worker health, strict safety requirements, and restrictions in organic production systems (Settimi et al., 2005).

In this context, and given the growing demand for sustainable practices, natural low-impact alternatives capable of inducing budbreak without compromising agroecosystem health are being explored; among these, garlic (*Allium sativum* L.) emerges as a promising option due to its richness in sulfur-containing compounds, which are associated with antimicrobial, antioxidant, and biostimulant properties (Block, 1992; Lawson, 1998).

Studies under controlled conditions have shown that the direct application of garlic paste on freshly pruned canes can induce budbreak at levels comparable to hydrogen cyanamide, with volatile sulfur compounds being primarily responsible for this effect (Kubota et al., 2000). Likewise, garlic extracts have demonstrated the ability to compensate for chilling deficiency in grapevine cuttings of the cultivar

Cabernet Sauvignon, promoting bud emergence even in the absence of winter chilling (Botelho et al., 2007).

At the field level, the use of garlic-based products has shown encouraging results. In subtropical climates with mild winters, increases in earliness, rate, and final percentage of budbreak have been observed (Botelho et al., 2010). Similarly, in high tropical regions characterized by the absence of chilling accumulation, the direct application of garlic extract to buds matched the effectiveness of hydrogen cyanamide, also reducing the mean time to bud emergence (Almanza et al., 2010).

These findings position garlic as a potential ecological alternative to synthetic inducers. Furthermore, to optimize bud exposure to garlic bioactive compounds, paste formulations are considered strategic, as they allow prolonged release of active compounds and reduce the volatilization of sulfur compounds, enhancing their interaction with cellular processes regulating dormancy release (Block, 1992; Kubota et al., 2000). Despite these advances, information on the effectiveness of garlic paste applied directly to buds under field conditions remains limited, particularly in viticultural regions with chilling deficiency such as the Moquegua Valley.

Based on these considerations, the present study aimed to evaluate the effectiveness of garlic paste (*Allium sativum* L.) as an ecological alternative to induce budbreak in grapevine (*Vitis vinifera* L.) cv. Italia. In this way, the study seeks to validate a low-impact technological tool capable of optimizing the phenological response of the crop, ensuring uniform and agronomically satisfactory dormancy release, and contributing to the productivity and sustainability of vineyards in the region.

METHODS

The study was conducted in an 8-year-old vineyard of cv. Italia (*Vitis vinifera* L.), trained under a trellis system, with a planting spacing of 2.5 m between rows and 2.0 m between plants. The experimental unit was located in the Siglo XXI sector, within the Pampas de San Antonio irrigation area, Moquegua region, southern Peru. The experimental area is situated at an altitude of 1322 m.a.s.l., with geographic coordinates of 17°13'25" S and 70°57'19" W. During the evaluation period, maximum temperatures ranged between 27.1 and 28.0 °C, while minimum temperatures ranged between 10.9 and 11.8 °C. These arid climate conditions reflect a deficiency in chilling accumulation, a limiting factor for the natural release of dormancy.

The experiment was established under a randomized complete block design (RCBD) with three treatments and three blocks, distributed in a total of nine

experimental units. The treatments consisted of an untreated control (no application), a chemical control (5% hydrogen cyanamide), and garlic paste (undiluted). The experimental population consisted of 45 plants, from which three plants per experimental unit were selected for evaluation.

Treatments were applied after pruning, directly onto the buds using a brush. To prevent rapid volatilization of bioactive compounds due to solar radiation, applications were carried out in the afternoon, and 5% aloe vera (*Aloe vera* L.) mucilage was added as a natural adhesive.

To determine the dynamics of dormancy release, seven periodic evaluations were conducted between 15 and 35 days after pruning (DAP), recording the buds that reached the green tip stage (Stage C) according to the scale of Baggiolini (1952), characterized by the visible emergence of leaf tips through the protective bud scales.

Based on these records, four variables were evaluated: onset of budbreak, defined as the number of days from pruning until the plant reached 10% budbreak (Lorenz et al., 1995); mean time to budbreak, estimating the number of days required to reach 50% budbreak; budbreak percentage, determined at 35 DAP; and relative efficiency, calculated using hydrogen cyanamide performance as the standard of maximum theoretical efficiency.

To evaluate the effect of the treatments, the data were subjected to analysis of variance (ANOVA) to determine the existence of significant differences. Subsequently, mean comparisons were performed using Tukey's test ($P \leq 0.05$). In addition, budbreak dynamics were modeled using quadratic regression analysis to estimate phenological parameters. All statistical analyses were performed using InfoStat software (Di Rienzo et al., 2020).

RESULTS

Budbreak dynamics

The periodic evaluation of buds allowed the establishment of budbreak curves for the different treatments over a period of 35 days after pruning (DAP) (Figure 1). It was observed that the application of inducers significantly modified the natural behavior of the vine. From the first evaluation at 15 DAP, treatments with hydrogen cyanamide (T_1) and garlic paste (T_2) already showed a clear advantage, with 26.53% and 17.74% budbreak, respectively, compared to 6.20% in the control treatment (T_0).

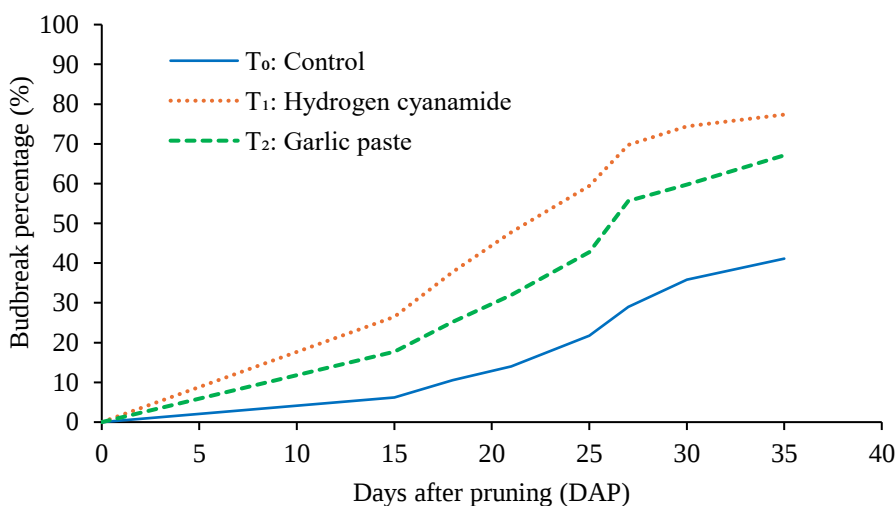


Figure 1. Budbreak dynamics.

Source: Own elaboration.

Throughout the evaluation period, this gap was maintained and widened considerably, reaching its greatest contrast around 25 DAP. At that point, treatments with hydrogen cyanamide (T_1) and garlic paste (T_2) exhibited accelerated growth dynamics, reaching 59.41% and 42.74% budbreak, respectively, while the control remained in early stages of metabolic activation with only 21.78%. From this point onward, T_1 began to stabilize its curve, with more than 70% of its buds at the green tip stage by 35 DAP. In contrast, garlic paste (T_2) maintained a steady and parallel upward trend, showing sustained induction capacity by exceeding 60% budbreak toward the end of the evaluation. Meanwhile, T_0 exhibited a slower and less uniform response.

This difference in budbreak kinetics observed in T_1 and T_2 compared to the control suggests that both treatments effectively stimulated bud activation. In the case of hydrogen cyanamide (T_1), the rapid response observed agrees with that reported by Shulman et al. (1983) and Dokoozlian et al. (1995), who indicate that this compound promotes early and relatively uniform budbreak, resulting in a rapid increase in the number of sprouted buds during the initial stages after pruning. As most physiologically active buds initiate development, the budbreak rate tends to decrease, explaining the progressive stabilization observed in the final phase of the curve.

In the case of garlic paste (T₂), the observed behavior could be related to the physical characteristics of the formulation used, since paste-based preparations prolong the contact time of bioactive compounds with the bud scales, reducing their rapid volatilization. According to Kubota et al. (2000), this greater persistence favors a gradual release of garlic compounds, which may induce progressive bud activation and explain the continuous upward trend observed in the budbreak curve.

Budbreak onset

The application of inducers markedly advanced the onset of budbreak compared to the untreated control. Treatments with hydrogen cyanamide (T₁) and garlic paste (T₂) recorded mean values of 11.88 and 13.03 DAP, respectively, with no statistical differences between them (Table 1). In contrast, the untreated control (T₀) showed a longer latency period, requiring 17.76 DAP to reach the same phenological threshold.

Table 1. Mean comparison of budbreak onset.

Treatment	Mean $\pm$ DE (dap)	Significance
T ₁ : Hydrogen cyanamide	11,88 $\pm$ 0,62	a
T ₂ : Garlic paste	13,03 $\pm$ 1,14	a
T ₀ : Control	17,76 $\pm$ 0,89	b

Source: Own elaboration.

This precocity achieved by both garlic paste and hydrogen cyanamide demonstrates the capacity of these compounds to promote dormancy release under conditions of insufficient chilling accumulation. This phenological response is associated with the reactivation of metabolic processes within the bud. According to Or et al. (2002), the application of chemical inducers triggers a series of biochemical reactions that lead to the transient inhibition of the catalase enzyme, resulting in the accumulation of hydrogen peroxide (H₂O₂). This increase in H₂O₂ generates a controlled oxidative stress that acts as a key physiological signal, triggering the expression of genes associated with the cell cycle and carbohydrate metabolism, thereby promoting the transition from dormancy to active growth.

In agreement, Vargas-Arispuro et al. (2008) state that sulfur compounds in garlic, such as diallyl disulfide, can induce changes in bud signaling pathways in a manner analogous to hydrogen cyanamide. Under this physiological principle, the observed advancement suggests that the ecological alternative (T₂) was able to emulate the effect of the synthetic product (T₁), ensuring rapid dormancy release and successfully advancing the onset of budbreak.

Mean budbreak time

The evaluated treatments showed clear differences in budbreak response. Hydrogen cyanamide (T₁) recorded the fastest response, with an average of 21.19 DAP. Garlic paste (T₂) required 26.77 DAP, showing a difference of approximately 5.5 days compared to the synthetic inducer, although without statistically significant differences. In contrast, the untreated control (T₀) presented the longest estimated time, requiring 39.10 DAP, reflecting a prolonged phenological dormancy in the absence of budbreak inducers. These results confirm that chilling accumulation under the agroclimatic conditions of the Moquegua valley is insufficient to promote timely and uniform budbreak in grapevine.

Table 2. Mean comparison of mean budbreak time.

Treatment	Mean $\pm$ DE (dap)	Significance
T ₁ : Hydrogen cyanamide	21,19 $\pm$ 1,19	a
T ₂ : Garlic paste	26,77 $\pm$ 1,51	a
T ₀ : Control	39,10 $\pm$ 3,81	b

Source: Own elaboration.

When comparing the inducers, the shorter time required by hydrogen cyanamide (T₁) is associated with its rapid physiological action, which induces early dormancy release through alteration of the redox balance in bud tissues (Pérez & Lira, 2005). However, although garlic paste (T₂) exhibited a slightly more gradual kinetic response, it was able to induce 50% budbreak within a similar time frame to that of the synthetic inducer. From a physiological perspective, this response suggests that organosulfur compounds present in garlic may promote metabolic processes associated with reserve mobilization and the progressive reduction of abscisic acid levels, facilitating the transition from dormancy to active growth (Zheng et al., 2018).

Budbreak percentage

At the end of the evaluation period at 35 DAP (Table 3), hydrogen cyanamide (T₁) achieved the highest budbreak rate with 77.36%, followed by garlic paste (T₂) with 67.11%. In contrast, the untreated control (T₀) showed the lowest level of budbreak, reaching only 41.12%, also highlighting the need for the use of inducers to compensate for chilling deficiency.

Table 3. Mean comparison of budbreak percentage.

Treatment	Mean $\pm$ DE (%)	Significance
T ₁ : Hydrogen cyanamide	77,36 $\pm$ 1,34	a
T ₂ : Garlic paste	67,11 $\pm$ 3,93	b
T ₀ : Control	41,12 $\pm$ 5,17	c

Source: Own elaboration.

Budbreak percentage is one of the most relevant indicators for evaluating the effectiveness of inducers, as it directly determines the potential number of productive shoots in the vineyard and, consequently, crop yield (Dokoozlian et al., 1995; Lavee & May, 1997). The low response observed in the control confirms that, under conditions of limited chilling accumulation, grapevine buds have difficulty overcoming dormancy naturally, resulting in delayed and non-uniform budbreak.

In contrast, the application of inducers significantly increased the proportion of activated buds. Although hydrogen cyanamide recorded the highest budbreak percentage, the value achieved by garlic paste is agronomically relevant, as percentages close to 70% are generally considered sufficient to ensure a shoot density capable of sustaining crop productivity. This behavior confirms the findings of Botelho et al. (2010) and Almanza et al. (2010), who demonstrated that garlic-based products not only accelerate phenology but also substantially increase final budbreak percentage under conditions of low chilling accumulation, consolidating their role as a tool capable of ensuring productive viability without reliance on conventional agrochemicals.

Relative efficiency (RE)

The analysis (Table 4) determined that garlic paste (T₂) achieved an average efficiency of 86.71% relative to hydrogen cyanamide. In contrast, the natural process observed in the control (T₀) represented only 53.11% efficiency compared to the commercial standard.

Table 4. Mean comparison of relative efficiency.

Treatment	Mean $\pm$ DE (%)	Significance
T ₁ : Hydrogen cyanamide	100,00 $\pm$ 0,00	a
T ₂ : Garlic paste	86,71 $\pm$ 3,65	b
T ₀ : Control	53,11 $\pm$ 6,09	c

Source: Own elaboration.

The evaluation of relative efficiency provides insight into the balance between productivity and sustainability. Although statistically garlic paste shows a 13.17% lower efficiency compared to hydrogen cyanamide, this difference is largely offset by the ecological and biosafety advantages it offers. Hydrogen cyanamide is a highly toxic compound that requires strict application protocols and poses documented risks to agricultural workers and the environment (Settimi et al., 2005). Achieving close to 90% efficiency with a biopreparation such as garlic paste confirms that it is possible to transition toward agrochemical-free viticultural management in the Moquegua valley, while maintaining budbreak thresholds that ensure crop competitiveness without compromising ecosystem health.

CONCLUSIONS

Under conditions of low winter chilling typical of the Moquegua valley, garlic paste proved to be an effective alternative, consistently modifying the phenology of grapevine cv. Italia. Its application significantly advanced both the onset and the mean time to budbreak compared to the untreated control, resulting in an earlier and more homogeneous temporal response. This early dynamic exhibited a statistically similar effect to that of hydrogen cyanamide, supporting its use as an organic inducer for dormancy release in this crop.

Beyond the timing of the response, the positive effect of garlic paste was also reflected in budbreak percentage and relative efficiency, substantially outperforming the untreated control. Although the synthetic standard maximized total budbreak, the level achieved by the natural alternative ensures its full technical suitability. This supports its role as an ecological alternative to hydrogen cyanamide in scenarios where occupational safety, agroecology, and sustainability are prioritized, while maintaining the productive uniformity required for commercial success.

Overall, the results support the operational feasibility of garlic paste in vineyards under chilling-deficient conditions. Its adoption represents a significant step toward promoting organic viticulture, offering a clean and sustainable strategy to ensure the productivity of cv. Italia in the warm valleys of southern Peru, while reducing dependence on conventional agrochemicals.

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APPLICATION OF THE NEURAL NETWORK MODEL TO DETERMINE THE INFLUENCE OF EDUCATIONAL STRATEGIES ON ACADEMIC PERFORMANCE IN STUDENTS OF THE LICEO ITALIANO EDUCATIONAL INSTITUTION OF CUSCO, 2024

Rodriguez Quispe, David

ABSTRACT

This research aimed to determine the influence of educational strategies on academic performance using a neural network model at the Liceo Italiano del Cusco Educational Institution in 2024. The research methodology was basic, with a quantitative approach, correlational scope, and a non-experimental, cross-sectional design. The population consisted of 123 students from the Liceo Italiano del Cusco Educational Institution in 2024, and this research included the entire population. The results obtained in this research, using neural networks as a tool to determine the influence of educational strategies on academic performance, showed that the model demonstrates that all educational strategies (pre-instructional, co-instructional, and post-instructional) have a positive influence on academic performance. Pre-instructional strategies show a strong impact on neuron 1 (weight of 37.37) and a moderate impact on neuron 2 (weight of 1.27), while co-instructional strategies show a moderate positive influence on both neurons (weights of 11.35 and 1.07, respectively). Post-instructional strategies have the greatest influence on neuron 1 (weight of 43.91) and also a positive effect on neuron 2 (weight of 2.09). These activations, in turn, significantly influence the output, with weights of 0.84 and 2.34, confirming a positive influence, which means that the increase in educational strategies directly benefits academic performance.

Keywords: Educational strategies, Academic performance, Neural networks, Influence.

INTRODUCTION

Academic performance is a key element in education, as it evaluates students' academic achievements and their clear relationship to the knowledge acquired within the predetermined learning curriculum (Ariza et al., 2018). This simple yet objective concept is closely related to the learning strategies employed during class

sessions and to the psychological factors that influence students' educational performance. International studies, such as those in Colombia, have demonstrated that educational strategies have a significant impact on academic performance, highlighting their importance in improving results in different contexts. However, in developing countries, such as Peru, educational outcomes still reflect significant challenges. According to the Ministry of Education (MINEDU, 2022), less than 25% of students reach satisfactory levels in reading comprehension and mathematics, demonstrating low academic performance. In Cusco, this situation persists, with similar or lower percentages across different grade levels. Given this scenario, and considering the relevance of educational strategies as fundamental tools for promoting learning and holistic development (Pimienta, 2012), this research analyzes the influence of educational methodologies applied in learning sessions on academic performance using an unconventional neural network model at the Liceo Italiano Educational Institution in Cusco, 2024, thus providing an innovative approach to addressing this issue. This research is theoretically justified by the premise that the correct use or application of neural network models to the impact of different teaching and learning strategies on academic performance allows for leveraging the potential of machine learning in the academic field. It can therefore be established that both complex and multivariate variables influence students' academic outcomes. This approach is theoretically justified by the ability of neural networks to identify patterns and correlations in large, non-linear datasets, thus facilitating the precise and detailed identification of relationships between various pedagogical strategies and students' academic performance levels. As advanced predictive models, neural networks can effectively process both quantitative and qualitative variables, enabling a comprehensive evaluation of factors such as collaboration, ICT use, and active learning methodologies. These factors have been shown to significantly improve retention and comprehension skills in students at different academic levels. In practical terms, the model provides tangible value to the local educational community. By revealing complex learning patterns, it will allow teachers and administrators to identify the most effective strategies, optimize resources, and adapt teaching to the specific needs of students, thereby promoting a more personalized, inclusive, and high-quality education.

The methodological justification explains that the choice of neural networks is appropriate due to their capacity to analyze deep, non-linear relationships between educational variables and performance. This tool not only facilitates the precise identification of the most impactful factors but also allows for the simulation of scenarios to optimize teaching and learning strategies.

Regarding the economic justification, the study seeks to optimize educational investment. By identifying the most effective pedagogical strategies, spending on

ineffective resources and practices is avoided, directing funds toward methodologies that truly improve performance. This maximizes the return on investment, improving long-term institutional performance.

In the research conducted by Gil and Quintero (2021), "Prediction of Student Academic Performance with Artificial Neural Networks," the results indicate that the developed ANN correctly classifies 73% of the sample and performs better in metrics than other supervised learning techniques. Based on the results found, they concluded that early identification of academic performance allows for the development of didactic and pedagogical strategies that improve the teaching and learning process.

Incio et al. (2023) obtained the most outstanding results for the neural network when 85% of the data was used for training, 10% for validation, and 5% for testing. For each algorithm, 10 runs were performed with 14 neurons in the hidden Levenberg-Marquardt layer and 50 for Scaled Conjugate Gradient, achieving optimal MSE and R values. It was demonstrated that a network trained with the Levenberg-Marquardt (LM) algorithm has a predictive power of 86%, and a network trained with a scaled conjugate gradient (SCG) algorithm has a predictive power of 70%. This research concludes that neural networks applied to the educational field are effective tools for predicting academic performance and allow teachers to make informed decisions regarding the implementation of pedagogical strategies. The LM algorithm achieved greater predictive effectiveness.

In the research conducted by Castañeda et al. (2023) entitled "Artificial Neural Networks: A Measurement of Forecasting Learning as Potential Demand." The results obtained from the averages in conceptual forecasting learning and the neural network method were significant. In turn, machine and deep learning contributed to the progress in solving the problem. Regarding deep learning of student behavior, it was crucial, since the results obtained through forecasting favored modifications in the neural network, allowing it to acquire the ability to learn more complex functions. In conclusion, artificial neural networks applied to deep learning in forecasting significantly improve learning in concepts, procedures, and behaviors, allowing companies to reduce costs and increase profits in various aspects.

Capuñay (2021), in his research entitled "Neural Network-Based Model to Project the Academic Performance of Second-Year Secondary School Students at Educational Institution No. 16093-Jaén," found that the neural network implementation achieved an accuracy of 88.67% in predicting the average, rounded to the nearest whole number. Furthermore, considering the difference from the actual average value of ± 1 point, the predictive validity was 98.52%. In conclusion, these results guarantee high reliability in estimating the students' average.

Puga and Torres (2023), in their research entitled “Artificial Neural Networks to Predict the Academic Performance of Systems and Computer Engineering Students at the National University of the Peruvian Amazon,” used tools such as MATLAB Neural Network Toolbox and MS Excel, as well as artificial neural networks, to obtain the results for analysis. Results were obtained with an accuracy of 97.6%, a completeness of 100%, and a precision of 97.9%, with a %E of 2.083 and a CE of 0.196274, surpassing the results achieved in similar studies. In conclusion, the study demonstrated that machine learning methods are effective in predicting academic performance in the Linear Algebra course, achieving results superior to those of previous studies.

The overall objective is to determine the influence of educational strategies on academic performance using a neural network model at the Liceo Italiano Educational Institution in Cusco, 2024.

MATERIALS AND METHODOLOGY

Type of Research

This research will be basic in nature, as it will focus on generating new theoretical knowledge without the intention of solving immediate practical problems. According to Hernández et al. (2014), basic research aims to expand knowledge in a specific area, without seeking immediate applications. In this case, the study seeks to evaluate the influence of educational strategies on academic performance through the application of a neural network model, which allows for a deep and systematic analysis of the relationship between the variables.

Research Approach

The research will adopt a quantitative approach, centered on the collection and analysis of numerical data to measure phenomena and validate hypotheses using statistical instruments, as defined by Hernández et al. (2014). Specifically, a neural network model will be used to evaluate the influence of educational strategies on academic performance. Furthermore, it will have a correlational scope, as it will seek to analyze the relationship between the variables "educational strategies" and "academic performance" without manipulating them, determining the degree of association between them (Hernández et al., 2014).

Research Design

This research will be developed under a non-experimental, cross-sectional design, since the study variables will not be manipulated and the data will be collected at a single point in time. According to Hernández et al. (2014), this type of design is appropriate when seeking to observe phenomena in their natural context

and when information needs to be obtained at a specific time. In this case, the influence of educational strategies on the academic performance of students at the Liceo Italiano del Cusco school will be evaluated, allowing for a snapshot of the impact at the time of data collection.

Study Population

In this research, the study population will consist of 123 students from the aforementioned educational institution. These students will be selected by grade level, which will allow for obtaining valuable information about the effectiveness of the research.

Data Collection Techniques

The research will employ multiple data collection techniques to ensure the validity and reliability of the results. These include: student surveys on educational strategies and perceptions of learning; the collection of academic data (such as grades) to measure performance; an analysis of historical data to identify trends; and interviews with teachers to obtain perspectives on the effectiveness of these strategies. This mixed-methods approach allows for a comprehensive view of the subject of study.

Techniques for Testing the Truth or Falsity of the Hypotheses

Descriptive and inferential statistical analyses (such as the Student's t-test or ANOVA) will be used to evaluate the relationship between variables and determine whether educational strategies influence academic performance. In addition, cross-validation will be used in a neural network model to verify its predictive capacity and robustness. These techniques guarantee a rigorous approach to testing the hypotheses.

RESULTS

Descriptive analysis of general data

Table 1: Sex of students at the I.E. LICEO ITALIANO DEL CUSCO, 2024

Sex	fi	%
Male	75	62%
Female	46	38%
Total	121	100%

Analysis and Interpretation

Table 1 shows the gender distribution of students at the Liceo Italiano del Cusco school in 2024. It can be seen that 62% of the students are male, representing a total of 75 students, while the remaining 38% are female, totaling 46 students. This indicates a predominance of male students in the institution, with a difference of 24% compared to the female group.

Results in relation to the objectives

Table 2: Training and testing population

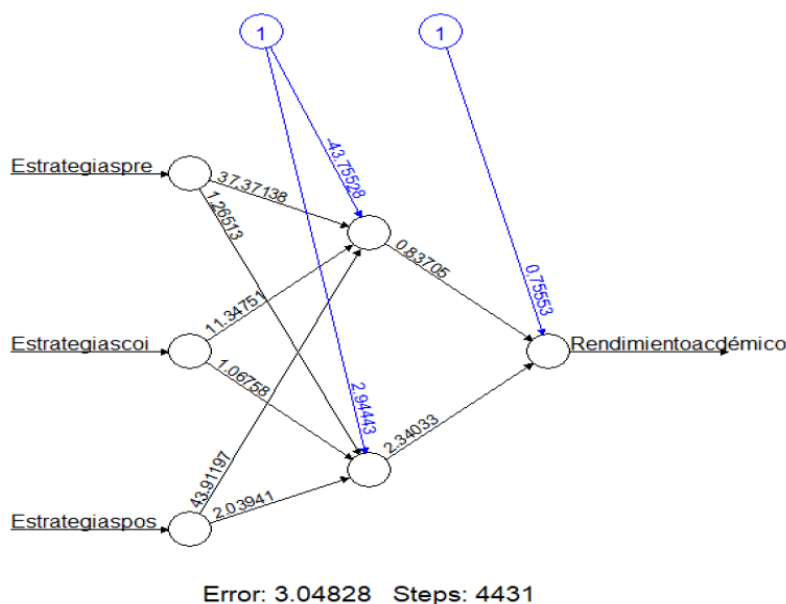
	n	%
Training	96	79%
Population testing	25	21%
Total	121	100%

Dividing data into training and test sets is fundamental for training machine learning models. The training set is used to fine-tune the model's parameters, while the test set evaluates its ability to generalize to unseen data, helping to detect overfitting issues. Furthermore, this separation ensures an objective evaluation of the model's performance and allows for adjusting hyperparameters without compromising the final evaluation. In short, it guarantees that the model is robust, does not overfit the training data, and performs well on new data. It also helps reduce the error obtained. In this research, 96 students from the Liceo Italiano del Cusco educational institution will be included in the training set, and 25 in the test set.

Table 3: Summary of samples

input layer	factors	Pre-instructional strategies	Co-instructional strategies	Post-instructional strategies
	Covariables	p1, p2, p3, p4, p5, p6, p7, p8, p9, p10	p11, p12, p13, p14, p15, p16, p17, p18, p19, p20	p21, p22, p23, p24, p25, p26, p27, p28, p29, p30
	Layer	1		
hidden layer	Neurons	2		
	Function of activation	Logistics		
output layer	Variable dependent	Academic performance (AD, A, B, C)		

Figure 1: Neural network model

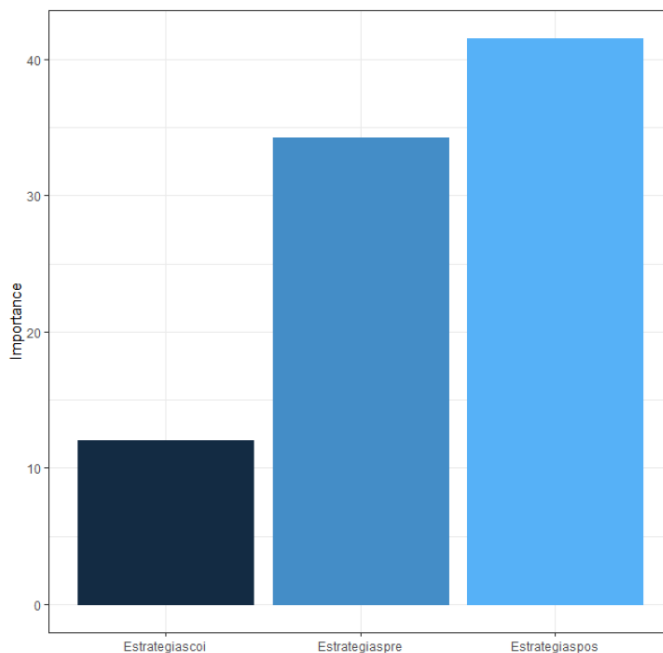


Interpretation

Figure 1 shows that the model has three input variables: Pre-instructional Strategies, Co-instructional Strategies, and Post-instructional Strategies, with a hidden layer containing two neurons, and an output layer with the independent variable Academic Performance. The figure shows the weights of the three input variables in the hidden layer with respect to each hidden neuron. These weights indicate the influence that the input variables will have on our independent variable, which is educational strategies. Regarding pre-instructional strategies, it indicates that it will have a strong and positive influence on the first neuron of the hidden layer, which has a value of 37.37. This indicates that if pre-instructional strategies increase, the activation of the first neuron also increases. On the other hand, a lower value is observed regarding the influence of this dimension on the second neuron, which is 1.27. This value indicates a positive influence, meaning that if there is an increase in pre-instructional strategies, there will also be an increase in the activation of the second neuron. On the other hand, regarding co-instructional strategies, a value of 11.35 is observed. This value indicates a positive influence, as with the previous values. This suggests that if co-instructional strategies are increased, there will also be an increase in the activation function of neuron 1. Regarding neuron 2, a value of 1.07 is observed, also indicating a positive influence. This means that an increase in co-instructional strategies will also affect the

activation function of neuron 2. Finally, we have post-instructional strategies, which obtained a value of 43.91 with respect to neuron 1. This value indicates that post-instructional strategies will positively influence the activation function of neuron 1. Regarding neuron 2, a value of 2.09 indicates a positive influence of post-instructional strategies on its activation function. From neuron 2, the influence observed between the neurons and the output layer indicates that the activation of the first hidden neuron has a positive impact on the output, and an increase in its activation will increase the value of academic performance proportionally to its weight of 0.84. Similarly, hidden neuron 2 has a positive value of 2.34, which indicates that the hidden neuron significantly and positively influences the output layer. Considering that a positive influence was obtained in all three types of strategies, it is concluded that there will be a positive influence of educational strategies on academic performance. An error of approximately 3.05 is observed; this error could be due to a variety of factors related to the data, the model configuration, and its training. To find the most optimal weights, the model performed 4431 iterations.

Figure 2: Influence of dimensions



Interpretation

The present bar graph indicates the influence or importance of the three input variables in the model that was carried out. It can be observed that the three strategies will significantly and positively influence academic performance. The

one that shows the greatest influence is the post-instructional strategies, followed by the pre-instructional strategies and then the co-instructional strategies. This graph was created using the weights obtained in the model.

Table 4: Confusion Matrix

		Prediction			
		C	B	A	AD
Current	C	4	0	0	0
	B	0	10	1	1
	A	0	0	3	0
	AD	0	2	0	4

Accuracy (Exactitud)

$$Accuarecy = \frac{TP + TN}{TP + TN + FP + FN}$$

In the present investigation, an accuracy of 0.84 was obtained. This result indicates that the prediction model has good performance, which indicates that the predictions of academic performance with respect to educational strategies, taking into account its three dimensions, are accurate.

Sensitivity and specificity

$$\text{Sensibility} = \frac{TP}{TP + FN}$$

$$\text{Specificity} = \frac{TN}{TN + FP}$$

Table 5: Sensitivities and specificities

Performance academic	Sensitivities	Specificities
C	1	1
B	0.83	0.85
A	0.75	1
AD	0.8	0.9

The model demonstrates outstanding performance in predicting grade C academic achievement, with a sensitivity and specificity of 100%, indicating that it correctly identified all cases in this grade without any false negatives or false

positives. For grade A, the sensitivity is 83.33%, meaning it correctly identified 83.33% of positive cases, but missed 16.67% as false negatives, while the specificity is 84.61%, suggesting some false positives, incorrectly classifying some cases from other grades as grade 3. For grade B, the sensitivity is 75%, reflecting that it correctly identified 75% of positive cases, but missed 25% as false negatives, while the specificity is a perfect 100%, meaning it avoided false positives. Finally, regarding AD notes, the model has a sensitivity of 80% and a specificity of 90%, indicating that it has correctly identified 80% of the positive cases, with 20% false negatives, and has correctly identified 90% of the negative cases, with 10% false positives.

DISCUSSION

In this research, positive synaptic weights were obtained, indicating a positive relationship between the three dimensions analyzed and the two hidden neurons in the model. The synaptic weights corresponding to these neurons are 0.83 for neuron 1 and 2.34 for neuron 2, demonstrating a significant influence of the following dimensions: pre-instructional strategies, co-instructional strategies, and post-instructional strategies.

Furthermore, this influence was represented in a bar graph with a standardized scale to facilitate its interpretation. The results showed that post-instructional strategies have the greatest impact on academic performance, followed by pre-instructional strategies, and finally, co-instructional strategies. This suggests that educational strategies have a significant and positive influence on the academic performance of students at the I.E. Italian Lyceum of Cusco, 2024.

In the research conducted by Gil and Quintero (2021), based on their findings, they concluded that the early identification of academic performance allows for the development of didactic and pedagogical strategies that improve the teaching and learning process. These results or conclusions are similar to those found in the present research, since this research evaluated three types of educational strategies, which positively influenced academic performance.

On the other hand, in the research by Incio et al. (2023), in that study, they performed the same data separation for training and testing as in the present research, achieving a predictive power of 70%, while in the present research, a predictive power of 84% was obtained. These differences could be due to the amount of data or the difference in the number of nodes used in the two studies. Incio et al., based on the results obtained, concluded that neural networks are an effective tool in the educational field, as they allow for informed decisions regarding the implementation of pedagogical strategies. Similarly, in the present

research, it was observed that neural networks are a useful tool for observing the influence that different educational strategies will have on educational performance.

According to the conclusion reached in the research by Castañeda et al. (2023), which indicates that artificial neural networks applied to deep learning in prediction significantly improve learning in concepts, procedures, and behaviors. This conclusion is similar to the present research, which found that educational strategies have a positive influence on academic performance. On the other hand, the research conducted by Capuñay (2021) had a prediction accuracy of 88.67%, a result very similar to the 84% found in the present research. This difference could be due to the amount of data or the number of hidden layers or nodes in the models.

In the research by Puga and Torres (2023), the neural network model achieved a high and good accuracy of 97.9%. Similarly, the present research found a high and good accuracy of 84%. Puga and Torres also obtained a very small error of 2.03, while the present research yielded a minimal error of 3.05. These errors could be attributed to the relationship between the factors or to overfitting. Puga and Torres concluded that machine learning methods are effective in predicting academic performance in Linear Algebra. Likewise, the results of the present research indicate that educational strategies positively influence student performance.

In summary, after comparing the results with the background of the research, several similarities and differences were identified, attributable to the specific contexts of each study.

CONCLUSIONS

Regarding the general objective, the results obtained demonstrate that educational strategies have a significant and positive influence on academic performance. This suggests that implementing appropriate strategies at each stage of the teaching-learning process can enhance students' academic performance. The developed model showed that, although each type of strategy has a different impact, all contribute positively to academic performance.

Regarding the first specific objective, pre-instructional strategies have a notable influence, especially on the first hidden neuron, with a high synaptic weight of 37.37. This indicates that adequate preparation before classes can have a significant impact on model activation and, consequently, on students' academic performance. Although the influence on the second neuron is lower, with a value of 1.27, it is still positive, confirming that these strategies are essential for effective learning. Regarding the second specific objective, it is concluded that co-instructional strategies also show a positive influence on both hidden neurons, with weights of 11.35 and 1.07. This highlights the importance of fostering effective interaction

during class time. These strategies allow students to remain engaged and actively participate, which contributes to strengthening their learning and performance.

Regarding the third specific objective, it is concluded that post-instructional strategies have the greatest influence on academic performance, with a weight of 43.91 on the first hidden neuron and 2.09 on the second. This suggests that activities carried out after class, such as reviews, summaries, and assignments, are crucial for consolidating learning. Their proper implementation ensures that students reinforce the knowledge acquired, achieving a more significant impact on their academic performance.

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ASSESSMENT OF WATER QUALITY IN THE ESPINAR-PUNO STABILIZATION LAGOON 2025

Sánchez Roque, Ronald

ABSTRACT

The main objective of this research was to comprehensively evaluate the environmental quality of the water in the Espinar Stabilization Lagoon, located in the city of Puno at 3810 m above sea level, in order to diagnose its current operational status, identify critical sources of pollution, and verify the level of compliance with the Environmental Quality Standards (ECA) established by the Ministry of the Environment. The methodology used was based on a physical-chemical and atmospheric monitoring design carried out on May 24, 2025 in four strategic areas: entrance, lagoon 1, lagoon 2, and exit. For the water assessment, a Hanna HI 98194 multiparameter meter was used to record parameters such as pH, temperature, electrical conductivity, salinity, and dissolved oxygen through direct in situ measurements. The results revealed that, in the water component, the pH (8.20–8.43) and water temperature (13.93–15.77°C) remained within the permissible limits according to national regulations. However, electrical conductivity reached a maximum of 2381 $\mu\text{S}/\text{cm}$ in lagoon 1, far exceeding the standard of 1000 $\mu\text{S}/\text{cm}$ set for the conservation of the aquatic environment. A critical finding was the condition of extreme anoxia at the inlet, with only 0.07% dissolved oxygen, although the system showed partial recovery towards the outlet with 10.56%. In conclusion, the lagoon presents heterogeneous functioning with partial non-compliance with the ECAs. Translated with DeepL.com (free version) where the inlet area is the point of greatest environmental impact due to the anaerobic decomposition of organic matter. There is an urgent need to optimize operational management through sediment removal, improved hydraulic mixing, and continuous monitoring to safeguard public health and the integrity of the Lake Titicaca ecosystem.

Keywords: Wastewater, stabilization pond, environmental monitoring, water quality, water pollution, environmental quality standards (ECA).

INTRODUCTION

Assessing water quality is a fundamental process for diagnosing the state of ecosystems and determining the impacts of human activities, especially in wastewater treatment systems such as stabilization ponds. The systematic measurement of physical-chemical and biological parameters allows changes in environmental quality to be identified, potential risks to be anticipated, and mitigation actions to be established aimed at protecting health and the natural environment.

Proper wastewater management is one of the greatest environmental challenges in urban and peri-urban areas of the country, especially in places where population growth and economic activities are developing rapidly. In this context, the city of Puno relies on the Espinar Stabilization Lagoon for the preliminary and biological treatment of its wastewater, making this infrastructure a strategic component for the protection of Lake Titicaca, one of the most vulnerable and ecologically, socially, and economically important high Andean ecosystems (Flores et al., 2020; Ministry of the Environment, 2017).

Stabilization ponds are systems that use physical, chemical, and biological processes to remove organic matter, nutrients, and microorganisms. These systems involve sedimentation, anaerobic digestion, photosynthesis, and aerobic oxidation processes (Matsumoto & Sánchez Ortiz, 2010), which allow for the gradual purification of water before it is discharged into receiving bodies.

The Espinar Stabilization Lagoon is located between Espinar Island and the Chanu-Chanu neighborhood, at 3,810 meters above sea level, and consists of two treatment bodies: a primary lagoon covering 13.4 hectares and a secondary lagoon covering 7.90 hectares. Its operation is based on natural processes and mechanisms of sedimentation, anaerobic digestion, and aerobic oxidation, whose performance can be affected by variations in pollutant load, climatic conditions, accumulation of solids, and deficiencies in the maintenance of structures such as screens, sand traps, and hydraulic distribution systems (Mara, 2004; Von Sperling, 2007). These vulnerabilities can compromise treatment efficiency and generate significant environmental risks both within the system and in its immediate surroundings (PAHO, 2016).

In recent years, the lagoon has been a source of concern due to the recurring presence of unpleasant odors, proliferation of vectors, discharge of effluents with parameters outside established standards, and possible impacts on nearby populations and agricultural activities in the area. These conditions are related to the accumulation of organic matter, low concentrations of dissolved oxygen, increased electrical conductivity, the presence of gases such as methane (CH₄) and

hydrogen sulfide (H₂S), as well as limited water circulation in certain areas of the system (Crites & Tchobanoglous, 2000; Aybar et al., 2019). These situations reflect an environmental problem that requires an updated, technical diagnosis that is compared with current regulations (MINAM, 2017).

In this regard, this study conducts a comprehensive assessment of water quality at four key points in the lagoon (inlet, lagoon 1, lagoon 2, and outlet) by measuring physical and chemical parameters characteristic of the stabilization process. Variables such as pH, temperature, electrical conductivity, salinity, and dissolved oxygen were analyzed for the water. The main objective is to identify the current state of the system, recognize trends in deterioration or concentration of pollutants, and assess the level of compliance with the Environmental Quality Standards (ECA) established by the Ministry of the Environment (MINAM, 2017; WHO, 2011).

This assessment is important because it provides accurate information for decision-making, the design of mitigation measures, and the planning of actions to improve lagoon management. It also constitutes a fundamental input for preventing risks to public health, minimizing negative impacts on aquatic ecosystems, and strengthening the environmental sustainability of wastewater treatment in the city of Puno (UNEP, 2018; García & Ramos, 2021). The diagnosis obtained will also guide future interventions for rehabilitation, operational optimization, or expansion of the system, in order to ensure efficient and environmentally safe operation (Mara & Pearson, 2019).

Ticona et al. (2021) The Espinar stabilization pond is a body of wastewater located in the district of Puno (region), which accumulates wastewater from the city of Puno, Peru. Measurements of pH, water temperature, total suspended solids, electrical conductivity, and salinity were evaluated. The results showed significant differences between the data from the influent and effluent samples during the periods analyzed (Kruskal Wallis). The median concentrations of the effluent for the parameters of temperature (16.6 °C), salinity (0.67 mg/L), pH (7.7 °C), total dissolved solids (669.00 ppm), and electrical conductivity (1463.07 µs/cm) show significant differences. Although these results are within the established limits, it is necessary to implement monitoring mechanisms for adequate control of the parameters evaluated and, in this way, prevent deterioration of the environment surrounding the lagoon.

METHOD

The methodology applied for the environmental assessment of the Espinar Stabilization Lagoon was based on an in-situ monitoring design. The study was

carried out on the main water component, establishing four strategic points to ensure hydraulic representativeness: inlet, lagoon 1, lagoon 2, and outlet.

To assess water quality, a Hanna HI 98194 Multiparameter meter was used, which was previously calibrated with standard solutions to ensure the reliability of the measurements. The parameters analyzed were pH, temperature, electrical conductivity, salinity, and percentage of dissolved oxygen. The procedure consisted of submerging the sensors to a sufficient depth to avoid distortions due to turbulence, recording the data in a field notebook once the readings stabilized. The final results were compared with the Environmental Quality Standards (ECA) for Water (Category 4) of D.S. No. 004-2017-MINAM.

The data recorded by the Hanna HI 98194 Multiparameter was processed in an Excel database and then analyzed using the InfoStat 2024 statistical program. To determine whether there were any differences in the monitoring performed, the Kruskal Wallis test was used with the INFOSTAT software, at a significance level of 95% with an alpha of 0.05.

RESULTS

pH: Figure 1 shows the pH values in different areas, indicating that the inlet has the highest value at 8.43, meaning that the water there is more alkaline, while lagoon 2 has the lowest value at 8.20, making it the least alkaline point. This variation could be due to factors such as the presence of dissolved minerals, the influence of human activities such as wastewater discharges, or natural processes such as photosynthesis and the respiration of aquatic organisms, which can locally modify the pH. In addition, differences in water flow could concentrate certain elements in specific areas, affecting their alkalinity.

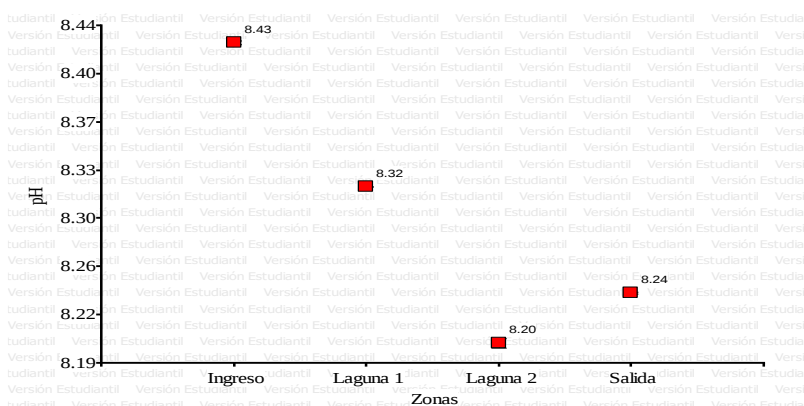


Figure 1

Levels of pH variation in wastewater in four study areas.

The pH levels in the four assessment areas are similar to those reported by Camacho-Ballesteros et al. (2020), who reported pH values in the range of 6.98, 7.54, and 8.32. Similarly, Rodríguez Heredia et al. (2020) reported pH levels ranging from 5 to 8 units. These results are below the Maximum Permissible Limits.

Table 1 shows that there is a difference in pH in the four zones (GL = 3; N = 100; $\alpha = 0.05$; $p = 0.0000$).

Table 1

Analysis of pH in the evaluation areas, applying the Kruskal-Wallis test with INFOSTAT software (May 2025).

Variable	Areas	N	Measures	D.E.	Medians	H	p
pH	Inlet	25	8.428	0.00645497	8.43	92.7034	0.0000
pH	Lagoon 1	25	8.32	4.9317E-15	8.32		
pH	Lagoon 2	25	8.202	0.01825742	8.2		
pH	Outlet	25	8.2396	0.00351188	8.24		

Source: own elaboration

Temperature. Figure 2 shows the temperature values in different study areas. The highest temperature (15.77°C) was recorded in lagoon 2, followed by the inlet area (15.05°C), while the outlet area and lagoon 1 had the lowest temperatures (13.95°C and 13.93°C, respectively). This distribution suggests a thermal variation probably influenced by factors such as sun exposure, which depends greatly on the time of day. The temperature in lagoon 2 could be related to its orientation towards the sun, which favors greater heating, while lagoon 1 and the outlet area could be subject to colder water currents, explaining the differences observed.

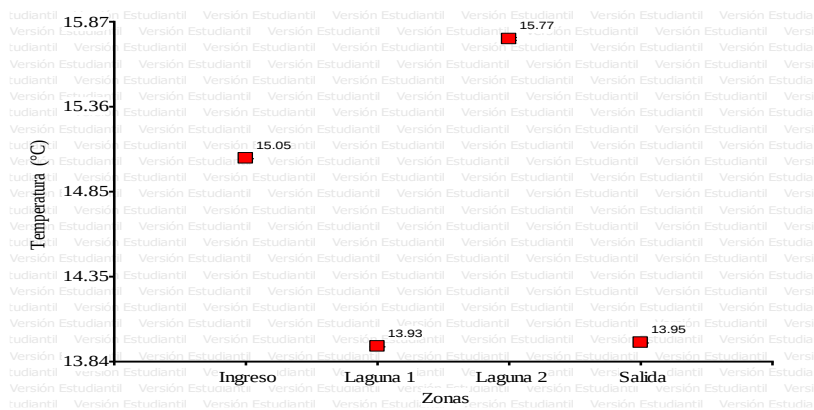


Figure 2

Temperature variation levels (°C) of wastewater in four study areas.

The temperature levels in the four assessment areas are below those reported by Matsumoto and Sánchez Ortiz (2010), who reported temperatures ranging from 27.5 to 29.9 °C. On the other hand, Cáceres Pom et al. (2021) reported a temperature of 25.5 °C. These results are below the Maximum Permissible Values (temperature < 35 °C).

Table 2 shows that there is a temperature difference in the four zones (GL = 3; N = 100; $\alpha = 0.05$; $p = 0.0000$). The entrance zone and lagoon 2 had the highest temperatures.

Table 2

Analysis of temperature in different monitoring zones in the stabilization pond, applying the Kruskal-Wallis test with INFOSTAT software (May 2025).

Variable	Areas	N	Measures	D.E.	Medians	H	p
Temperature (°C) Inlet		25	15.05	6.2366E-15	15.05	92.8218	0.0000
Temperature (°C) Lagoon 1		25	13.9312	0.00331662	13.93		
Temperature (°C) Lagoon 2		25	15.7656	0.04691126	15.77		
Temperature (°C) Outlet		25	13.95	6.2366E-15	13.95		

Source: own elaboration

Electrical conductivity: Figure 3 shows the variation in electrical conductivity (EC) in different areas of the stabilization pond, with values ranging from 1948 $\mu\text{S/cm}$ in pond 2 (water inlet) to 2381 $\mu\text{S/cm}$ in pond 1. In the water outlet area, conductivity was 1991 $\mu\text{S/cm}$, and in the inlet area, it was 2052 $\mu\text{S/cm}$, indicating a progressive increase in EC from the inlet to other areas of the pond, especially in pond 1. This difference may be due to factors such as the accumulation of dissolved salts through evaporation or decomposition of organic matter, biological processes that release ions, or the possible presence of wastewater discharges with a higher ionic load in certain areas. In addition, the lack of good mixing of the water within the lagoon could generate these spatial differences, showing how the internal dynamics of the system influence the distribution of conductivity.

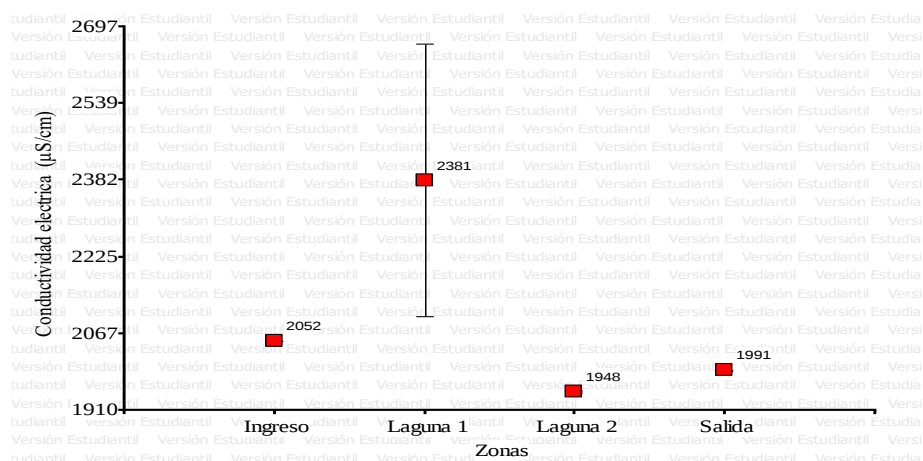


Figure 3

Levels of variation in electrical conductivity ($\mu\text{S}/\text{cm}$) of wastewater in four study areas in the Espinar stabilization pond in the city of Puno (May 2025).

The electrical conductivity levels in the four zones are above those reported by Camacho and Ballesteros et al. (2020), who reported an average conductivity of $475 \mu\text{S}/\text{cm}$. Meanwhile, Rodríguez and Heredia et al. (2020) reported a high conductivity of $2500 \mu\text{S}/\text{cm}$, which is similar to our results. When compared to the Environmental Quality Standards for Water Category 4, the conductivity is $1000 \mu\text{S}/\text{cm}$, which is above the limits.

Table 3 shows that there is a difference in electrical conductivity in the four zones (GL = 3; N = 100; $\alpha = 0.05$; $p = 0.0000$). The highest conductivity is found in the inlet zone and in the lagoon.

Table 3

Analysis of electrical conductivity in the different monitoring zones in the stabilization pond, applying the Kruskal-Wallis test with INFOSTAT software (May 2025).

Variable	Areas	N	Measures	D.E.	Medians	H	p
Electrical conductivity	Inlet	25	2051.64	3.4019	2052	92.7625	0.0000
Electrical conductivity	Lagoon 1	25	2381.16	1399.3437	2103		
Electrical conductivity	Lagoon 2	25	1947.64	9.81444	1946		
Electrical conductivity	Outlet	25	1991	2.0615	1992		

Source: own elaboration

Salinity: Figure 4 shows the salinity levels (PSU) at different points in the stabilization lagoon, with values varying slightly between areas. The inlet area has a salinity of 1.06 PSU, pond 2 has 1.01 PSU, the outlet area has 1.02 PSU, and pond 1 has the highest value of 1.08 PSU. This distribution suggests a slight spatial variation in the concentration of dissolved salts, probably influenced by factors such as partial evaporation in certain areas, the inflow of wastewater or natural water with different salt loads, or differences in water circulation within the lagoon. The higher salinity in lagoon 1 could indicate a gradual accumulation of salts due to localized evaporation processes or the influence of additional sources of salts, while the other areas show more uniform values, reflecting a lesser influence of these factors in those areas.

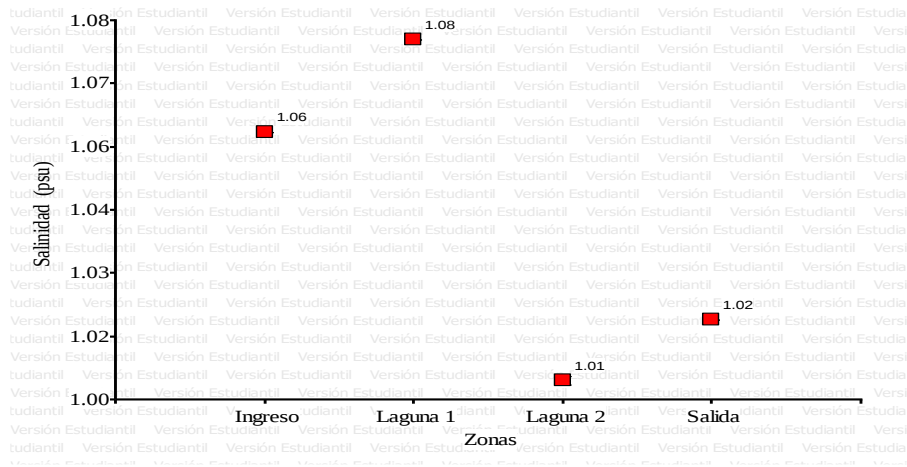


Figure 4

Salinity levels (psu) of wastewater in four assessment areas

According to Echeverría et al. (2024), water salinity is one of the causes of soil structure deterioration. It also decreases permeability and reduces crop yields due to its toxicity and osmotic effects. On the other hand, there is no reference to this parameter in our country's regulations for its corresponding evaluation.

Table 4 shows that there is a difference in salinity in the four areas (GL = 3; N = 100; $\alpha = 0.05$; $p = 0.0000$).).

Table 4

Analysis of salinity in the different assessment areas, applying the Kruskal-Wallis test with INFOSTAT software (May 2025).

Variable	Areas	N	Measures	D.E.	Medians	H	p
Salinity	Inlet	25	1.06	3.4447E-16	1.06	92.8218	0.0000
Salinity	Lagoon 1	25	1.08	6.5265E-16	1.08		
Salinity	Lagoon 2	25	1.0072	0.00458258	1.01		
Salinity	Oulet	25	1.02	3.0818E-16	1.02		

Source: own elaboration

Dissolved oxygen: Figure 5 shows the dissolved oxygen (DO) levels at different points in the stabilization pond, with values varying significantly between areas. The inlet area has the lowest value (0.07%), while pond 2 has 4.00%, the outlet area has a value of 10.56%, and pond 1 reaches 5.19%. This distribution indicates an inequality in the availability of dissolved oxygen, probably due to differences in water circulation, exposure to oxygen-consuming biological processes, or the influence of wastewater discharges rich in organic matter in the inlet area, which reduces dissolved oxygen (DO) in that area. In contrast, the outlet area appears to be a better oxygenated region, possibly due to greater water renewal or the presence of additional oxygen sources, such as algae photosynthesis. The low DO concentration in the east could reflect areas where microbial activity is high or where there is little mixing with air, which negatively affects water quality and can compromise the health of aquatic ecosystems.

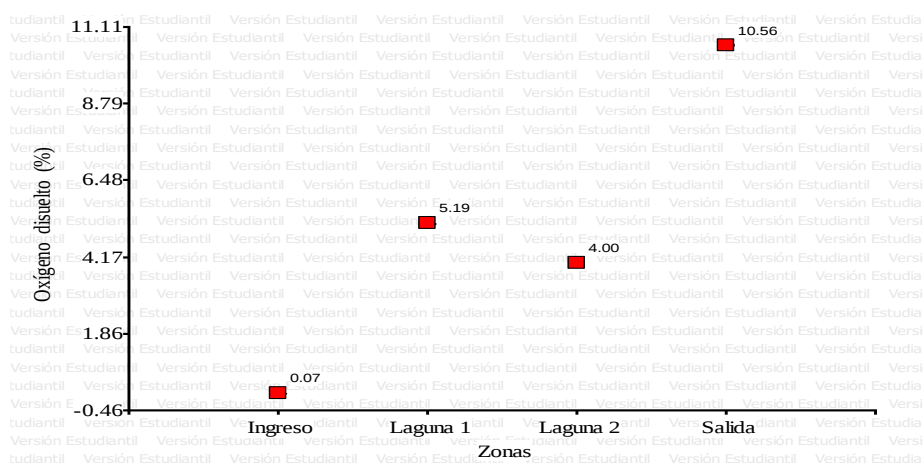


Figure 5

Levels of dissolved oxygen variation (%) in wastewater in four study areas.

Some of our dissolved oxygen concentrations are higher than those reported by Chibinda et al. (2017) for well water, whose values ranged from 3.2 to 3.7 mg/L. Similarly, Cusiche Pérez et al. (2019) reported values of 5.81 mg/L and 3.49 mg/L for wastewater.

Comparing with the Environmental Quality Standards for Water Category 4: the concentration of dissolved oxygen is ≥ 5 mg/L, in some areas it is above and below the established levels.

Table 5 shows that there is a difference in dissolved oxygen in the four zones (GL = 3; N = 100; $\alpha = 0.05$; $p = 0.0000$).

Table 5

Analysis of dissolved oxygen in the different study areas in the stabilization pond, applying the Kruskal-Wallis test with INFOSTAT software (May 2025).

Variable	Areas	N	Measures	D.E.	Medians	H	p
Dissolved oxygen	Inlet	25	0.07	3.8529E-17	0.07	92.8218	0.0000
Dissolved oxygen	Lagoon 1	25	5.192	0.08621678	5.2		
Dissolved oxygen	Lagoon 2	25	4	0	4		
Dissolved oxygen	Outlet	25	10.56	0.09574271	10.6		

Source: own elaboration

Impact assessment

Table 6

Assessment of environmental impacts, conducted in May 2025.

Component	Environmental Identification	Impact assessment		
		higt	Moderate	Low
Agua	1. Ph	8.43		
	2. Temperature (°C)	15.77		
	3. Electrical conductivity, (μS/cm)			2381
	4. Salinity (ptu)		1.08	
	5. Dissolved oxygen (%)			0.07

Source: own elaboration

For pH, the maximum permissible limits according to D.S. No. 003-2010-MINAM are (6.5 to 8.5), which are not exceeded by the monitoring carried out, so in this regard there is no negative environmental impact. For the temperature parameter, the maximum permissible limits are governed by D.S. No. 010 – 2019 – VIVIENDA, which is less than 35°C. In this case, the monitoring we carried out is below the regulations, so it does not generate a negative impact. However, for the electrical conductivity parameter, the results obtained are above the limits permitted by the governing standard. D.S. No. 004 – 2017 – MINAN, category 4, which is why we conclude that it has a negative impact on the “Espinar” stabilization lagoon in Puno. Similarly, for salinity, our results show a variation at different points; however, there is no regulation within the legislation that determines what is permissible for this parameter. However, for dissolved oxygen, the standard that establishes the limits is D.S. No. 004 – 2017 – MINAN, category 4, which establishes that the concentration must be less than 5 mg/L. According to our monitoring, it does not reach these levels, which generates a negative impact on the “Espinar” stabilization lagoon in Puno.

CONCLUSIONS

With regard to the pH values obtained, we can conclude that the inlet has the highest value at 8.43, which means that the water there is more alkaline, while lagoon 2 has the lowest value at 8.20, making it the least alkaline point. This variation could be due to factors such as the presence of dissolved minerals, the influence of human activities such as wastewater discharges, or natural processes such as photosynthesis and the respiration of aquatic organisms, which can locally modify the pH. However, we can also conclude that the pH does not have a negative impact, as it is within the permissible parameters.

Temperature is not a factor that generates a negative impact, as it is within the permissible parameters. Likewise, the highest temperature was recorded in lagoon 2 (15.77°C), followed by the inlet area (15.05°C), while the outlet area and lagoon 1 had the lowest temperatures (13.95°C and 13.93°C, respectively). This distribution suggests a thermal variation probably influenced by factors such as sun exposure, which depends greatly on the time of day. The temperature in lagoon 2 could be related to its orientation towards the sun, which favors greater warming, while lagoon 1 and the outlet area could be subject to colder water currents, explaining the differences observed.

Electrical conductivity (EC) ranges from 1948 $\mu\text{S}/\text{cm}$ in lagoon 2 (water inlet) to 2381 $\mu\text{S}/\text{cm}$ in lagoon 1. In the water outlet area, conductivity was 1991 $\mu\text{S}/\text{cm}$, and in the inlet area, it was 2052 $\mu\text{S}/\text{cm}$, this indicates a progressive increase in EC from the inlet to other areas of the lagoon, especially in lagoon 1. This difference may be due to factors such as the accumulation of dissolved salts through evaporation or decomposition of organic matter, biological processes that release ions, or the possible presence of wastewater discharges with a higher ionic charge in certain areas. In addition, the lack of good water mixing within the lagoon could generate these spatial differences, showing how the internal dynamics of the system influence the distribution of conductivity. Likewise, these values are above the standards established by regulations and therefore represent a negative impact.

Salinity levels (PSU) at different points in the stabilization pond, with values varying slightly between areas. The inlet area has a salinity of 1.06 PSU, pond 2 has 1.01 PSU, the outlet area has 1.02 PSU, and pond 1 has the highest value of 1.08 PSU. This distribution suggests a slight spatial variation in the concentration of dissolved salts, probably influenced by factors such as partial evaporation in certain areas, the inflow of wastewater or natural water with different salt loads, or differences in water circulation within the lagoon. The higher salinity in lagoon 1 could indicate a gradual accumulation of salts due to localized evaporation processes or the influence of additional sources of salts, while the other areas show more uniform values, reflecting a lesser influence of these factors in those areas.

Dissolved oxygen (DO) levels vary significantly between areas. The inlet area has the lowest value (0.07%), while lagoon 2 has 4.00%, the outlet area has a value of 10.56%, and lagoon 1 reaches 5.19%. This distribution indicates an inequality in the availability of dissolved oxygen, probably due to differences in water circulation, exposure to oxygen-consuming biological processes, or the influence of wastewater discharges rich in organic matter in the inlet area, which reduces dissolved oxygen (DO) in that area. In contrast, the outlet area appears to be a better oxygenated region, possibly due to greater water renewal or the presence of additional oxygen sources, such as algae photosynthesis. The low DO concentration

in the east could reflect areas where microbial activity is high or where there is little mixing with air, which negatively affects water quality and can compromise the health of aquatic ecosystems. Comparing this with D.S. No. 004-2017-MINAM, in Category 4, dissolved oxygen must be ≥ 5 mg/L, in some areas it is above and below the established levels.

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PARACETAMOL AS AN EMERGING CONTAMINANT IN AQUATIC SYSTEMS

Valencia Tito, Kelley Yesica

ABSTRACT

Aquatic pollution from pharmaceutical waste has intensified in recent decades due to the increasing consumption of commonly used medications. Among these compounds, paracetamol stands out due to its high consumption and frequent detection in surface and wastewater. This study aims to critically analyze recent scientific evidence on the presence, environmental behavior, and ecotoxicological risks associated with paracetamol in aquatic systems. To this end, a systematic review of recent international publications was conducted. The results show a persistent presence of the compound in various water bodies, as well as significant limitations of conventional wastewater treatment in achieving its complete removal. Consequently, although most studies originate from international contexts, their findings highlight real environmental risks. In the case of Peru, the limited local research and the complete absence of specific regulatory frameworks underscore the urgent need for greater scientific and regulatory attention to this emerging contaminant of growing concern in environmental health.

Keywords: emerging contaminants, ecotoxicology, paracetamol, environmental regulation, aquatic systems.

INTRODUCTION

The pollution of our rivers, lakes and seas by pharmaceutical waste has become an increasingly worrying environmental problem on a global scale (Alfaro, 2021). And among all those compounds, paracetamol stands out as one of the most consumed analgesics and antipyretics on the planet, with a production that easily exceeds tens of thousands of tons each year (Londoño et al., 2020). Furthermore, its over-the-counter availability in almost every country encourages massive and almost constant use, which ends up increasing its presence in the environment, especially through human urine and the improper disposal of expired or leftover pills (Carmona, 2019).

Numerous studies conducted in the last decade have found paracetamol in virtually all types of water bodies: rivers, wastewater, wells and aquifers, with concentrations ranging from nanograms to micrograms per liter; in some effluents from treatment plants in densely populated areas, values above 50 µg/L have even been measured (Jaimes & Vera, 2020). Although wastewater treatment plants manage to remove between 70% and 95% of the compound, they never manage to eliminate it completely, so it continues to enter aquatic ecosystems constantly (Macías, 2015). To make matters worse, the degradation process can produce byproducts that, in several cases, are even more toxic than the original paracetamol (Quiñonez, 2021). From an ecotoxicological perspective, the situation is equally concerning, as controlled experiments have demonstrated that prolonged exposure to levels above 10 µg/L generates oxidative stress, significant changes in liver enzymes, and visible liver damage in fish; it also produces a clear inhibition of growth in algae and small aquatic crustaceans (Condori, 2020). All these results make it clear that, although paracetamol remains a safe drug for humans when used correctly, its behavior once it leaves the body and reaches the environment represents a real risk that has not yet received the regulatory attention it deserves (Serna-Galvis et al., 2022).

In the specific case of Peru, this concern becomes even more urgent because current environmental legislation sets quite strict limits for classic pollutants (heavy metals, coliforms, etc.), yet completely omits any guideline values or specific standards for pharmaceutical residues such as paracetamol (Sansores, 2022). This legal gap greatly hinders both systematic monitoring and the design of concrete measures to control these emerging pollutants (Maldonado, 2018). Precisely for this reason, this article seeks to review the most recent scientific evidence on the presence of paracetamol in the environment and its actual ecotoxicological effects, while also analyzing the regulatory gaps that currently exist in Peru regarding this type of emerging micro-pollutant (Bellés, 2018).

THEMATIC DEVELOPMENT

Paracetamol as an Emerging Contaminant

Paracetamol has become one of the most prevalent emerging contaminants in aquatic matrices (Pachés, 2020). This is due to its high global consumption and its high excretion rate, between 90% and 100%, in the form of metabolites and untransformed fraction, which promotes its continuous release into the environment (Sandoval et al., 2020).

Several international studies have documented significant concentrations in different water compartments:

- In urban wastewater: between 5 and 120 µg/L
- In surface waters: from 0.1 to 25 µg/L, with variations associated with population density and the level of pretreatment.

Although it exhibits moderate biodegradability, its constant input generates a pseudo-persistence in the environment, especially in basins with direct domestic discharges (Donaires et al., 2022). Similarly, conventional treatment plants achieve variable removal efficiencies, averaging around 80%, resulting in persistent residual discharges into ecosystems (Tejada et al., 2014). Beyond its therapeutic safety, paracetamol meets the operational criteria for an emerging contaminant: frequent detection, quantifiable presence, and lack of specific regulation in multiple national contexts (Avaro, 2019).

Presence and concentrations in aquatic systems

Scientific evidence reveals the recurring presence of paracetamol in aquatic matrices in various countries (López-Rivas et al., 2023). In Spain, for example, concentrations in wastewater have been detected ranging from 4.8 to 98 µg/L; similarly, in Mexico, studies in urban rivers record values from 0.2 to 14 µg/L (León et al., 2023). Similarly, in Brazil, levels exceeding 60 µg/L have been identified in wastewater treatment plant effluents, while in China, concentrations in surface waters range from ng/L to 22 µg/L (Aguirre & Mendocilla, 2023).

These findings, obtained in different geographical and treatment contexts, confirm the global distribution and frequent detection of the compound in surface and wastewater bodies (RCE, 2015). Consequently, they demonstrate its status as a persistent emerging contaminant, regardless of regional differences in consumption, sanitation infrastructure, or wastewater treatment practices (Vallejo, 2017).

Environmental Behavior and Degradation

Paracetamol exhibits a relatively short half-life in aquatic environments, between one and seven days under aerobic conditions (Binder, 2007). However, its continuous discharge from anthropogenic sources generates significant environmental pseudo-persistence (Soto, 2017). Its degradation occurs mainly through photolysis and microbial biodegradation, resulting in metabolites such as p-aminophenol (Quintela et al., 2005). In conventional wastewater treatment plants, removal efficiencies range from 70% to 95%, although complete elimination of the compound is never achieved (Bustos, 2012; Quintela et al., 2005).

Ecotoxicological Impact

Recent ecotoxicological studies have demonstrated that paracetamol exerts significant adverse effects on non-target organisms in aquatic and terrestrial

ecosystems (Nieto, 2020). In particular, it induces oxidative stress and molecular damage in plants such as spinach, as well as causing physiological alterations in aquatic invertebrates (Torres, 2016). These disturbances can compromise the growth, reproduction, and overall health of various species exposed to relevant environmental concentrations of the drug.

Limitations of Wastewater Treatment

The limitations of wastewater treatment stem from well-documented technical, regulatory, and economic factors in the scientific literature. Globally, a significant proportion of domestic wastewater does not receive adequate treatment. In Latin America and the Caribbean, for example, approximately 42% of domestic wastewater is not safely treated before discharge, according to recent UN-Water reports (Tejada et al., 2014). In contrast, more developed regions achieve coverage rates exceeding 70–80% on average (Zamalloa-Cuba et al., 2021).

In developing countries, infrastructure is frequently insufficient, treatment plants operate with limited efficiency, and investment in advanced technologies is scarce. Consequently, the capacity to remove complex contaminants such as microplastics, antibiotics, or nutrients that require tertiary or specialized processes is reduced (Salcedo, 2019).

Furthermore, regulatory frameworks are often insufficient or applied laxly in various contexts (Zirena et al., 2018). Despite updating efforts, outdated directives generate persistent deficiencies, hindering the effective protection of receiving ecosystems in many cases (Ureña et al., 2018). Finally, economic and social barriers exacerbate the situation: lack of political priority for sanitation, high costs of modern technologies, and low community participation in reuse initiatives (Rivas & Alonso, 2011).

Regulatory Gaps in Peru

Despite having the Pharmaceutical Products Law, as well as technical standards for pharmacovigilance and sanitary registration issued by DIGEMID, implementation in Peru is weak (Espinoza, 2023). Indeed, products without adequate certification persist on the market due to insufficient controls and limited effective inspection (Gutierrez, 2018).

This situation contrasts sharply with the European Union's regulatory framework, where the EMA imposes more rigorous standards for quality, safety, and efficacy (CUE, 2020). Furthermore, it continuously updates safety warnings, including those for paracetamol, and applies harmonized assessment procedures (Vaca, 2022).

Likewise, Rivera (2018) mentions that in the Peruvian context, it is necessary to strengthen institutional capacity and harmonize regulations with international standards to overcome these gaps (Sánchez, 2019). It is worth noting that systematic national studies to quantify paracetamol in environmental matrices are not conducted, largely due to the high cost of analytical techniques such as HPLC, which limits the generation of local data (EPA, 2007).

CONCLUSION

The reviewed scientific evidence confirms that paracetamol acts as an emerging persistent contaminant in aquatic systems, with a global presence at concentrations ranging from ng/L to µg/L, pseudo-persistence due to continuous discharges, and incomplete removal (70-95%) in conventional treatments. Its ecotoxicological effects oxidative stress, liver damage in fish, and growth inhibition in algae and invertebrates represent a real risk at environmental levels. In Peru, the absence of specific limits in the Environmental Quality Standards (EQS) for pharmaceutical waste, along with weak regulatory implementation by DIGEMID and the lack of systematic national monitoring (limited by the cost of techniques such as HPLC), exacerbate the vulnerability of ecosystems like Lake Titicaca. Unlike the European approach (EMA and directives requiring mandatory environmental risk assessments), it is urgent to adopt specific regulations, local studies, and advanced technologies to mitigate impacts and protect environmental health.

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