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Maintenance management of physical infrastructure in educational institutions: a systematic review

Julisa del Rosario Quispe Vilca[1], Dennys Geovanni Calderón Paniagua[2], Grisely Rosalie Quispe Vilca[3], Isabel Evelyna Choque Siguairo[4], Alexander Nicolás Vilcanqui Alarcón[5]
[1]Postgraduate School, Universidad Privada de Tacna, Tacna, Perú
[2]Faculty of Civil Engineering, Architecture and Geotechnics, Universidad Nacional Jorge Basadre Grohmann, Tacna, Perú
[3]Faculty of Legal and Business Sciences, Universidad Nacional Jorge Basadre Grohmann, Tacna, Perú
[4]Faculty of Education, Communication Sciences and Humanities, Universidad Privada de Tacna, Tacna, Perú
[5]Faculty of Industrial Engineering, Universidad Tecnológica del Perú, Tacna, Perú

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ABSTRACT

The physical infrastructure of education in Latin America (LATAM) requires actions to ensure its conservation and maintenance in the different systems and levels. This is due to the absence of a maintenance programmed proposed by the State and the lack of trained personnel to implement it. The objective of this study was to analyze the importance of maintenance management of physical infrastructure in educational institutions. A systematic review was conducted following the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) methodology. The search process was carried out in the Scopus, ERIC, and Web of Science (WoS) databases, and eligibility criteria were established. The review covered the time interval between 2015 and 2023, and 16 English-language papers were selected. The results indicate that the lack of adequate and sustained investment, together with the lack of scheduled maintenance of educational infrastructure and the absence of structured maintenance plans, have a negative impact on student achievement. It is necessary for national and local governments to develop public policies focused on the conservation and improvement of educational infrastructure, incorporating modern management tools to facilitate this process.

Corresponding Author:

Dennys Geovanni Calderón Paniagua
Faculty of Civil Engineering, Architecture and Geotechnics
Universidad Nacional Jorge Basadre Grohmann
Miraflores S/N, Tacna 23000, Tacna, Perú
Email: dcalderonp@unjbg.edu.pe

1. INTRODUCTION

Educational institutions play a crucial role in global socioeconomic development, as they are physical spaces where knowledge is generated and future professionals are forged. This vital function demands effective maintenance strategies to ensure optimal performance and longevity [1], [2]. However, despite the constant increase in the number of school buildings, it is possible to observe a worrying lack of attention to their maintenance, compromising the educational quality and sustainability of these fundamental assets [3], [4]. This maintenance process has evolved. Its development has been motivated by technological advances, new maintenance techniques, sustainable resource management practices, globalization, geopolitical, demographic, socio-cultural conditions, and economic transformations [5].

The current state of educational infrastructure presents an alarming picture worldwide. In the United States, the Government Accountability Office (GAO) [6] revealed that more than half of public-school districts require substantial renovations to their facilities. Specifically, 41% of districts need to upgrade or replace ventilation, heating, and air conditioning systems in at least half of their schools, affecting more than 36,000 institutions nationwide. In addition, in 55 schools visited in six states, outdated systems were found to be leaking and structurally damaged, causing air quality and mold problems, and forcing temporary adjustments to class schedules.

In Latin America (LATAM), the situation is even more critical. According to the Economic Commission for LATAM and the Caribbean, in 2020, approximately 30% of LATAM students were attending schools without access to ensure a safe return to face-to-face classes. This reality underscores the profound inequality in the distribution of resources allocated to school infrastructure. Okoye *et al.* [7] noted that factors such as limited training and resources, access to the Internet, and infrastructure influenced the adoption of digital technologies for education. These elements contributed significantly to the challenges faced by higher education institutions (HEIs) in the LATAM region.

In Peru, despite the efforts made, significant challenges persist in educational infrastructure, especially in rural areas [8]. These include inadequate facilities, shortage of resources, and in some cases, institutions operating premises that do not meet minimum operating requirements. In addition, there is a notable lack of technological equipment, which is a crucial aspect in today's digital era [9]–[11]. To address these challenges, it is essential to consider aspects such as the fair and equitable management of resources, as well as their rational distribution and usefulness in meeting the needs of the school environment. In addition, accountability-oriented management is required to ensure transparency and efficiency in the use of resources [12], [13].

Public management (PM) plays a fundamental role in the efficient administration of resources, including educational infrastructure. Martínez [14] defines PM as "the exercise of the administrative function of government, which includes all processes, instruments, and actions carried out by public organizations to achieve their goals." This management encompasses the administration of economic and human resources, to implement effective policies and regulations. Vidal-Chamorro *et al.* [15] emphasize that PM is an "efficient form of resource management through the application of processes, developed to achieve the welfare of the population to give impetus to the development of a country." This approach stresses the importance of government strategies that transcend political cycles and generate lasting impacts on society.

The PM is a model of government aimed at increasing the effectiveness, economy, efficiency, and quality of service, consolidating itself as an unavoidable concern of any society [16]. Conceived as an efficient administration of resources by the state. The PM allows the execution of policies established by "national and international governmental entities, which need for their correct implementation an active subject, whose main mission is to manage the State's capital to solve social needs" [17]. Among the areas covered by PM is education, where enormous challenges are evident to achieve the sustainability of the entities that make up the education system.

The maintenance of educational infrastructures represents a complex and costly challenge. Studies indicate that maintenance activities can constitute up to 60% of the total costs during the life cycle of a building [18], [19]. This reality demands the implementation of integrated operational methods that optimize performance and reduce long-term costs. Lu *et al.* [20] asserts that efficient maintenance management contributes to the sustainability of equipment and infrastructure lifetime by fulfilling activities such as planning, monitoring, and control. Meanwhile, Ma *et al.* [21] describe it as the strategic organization of resources to address maintenance problems and maximize return on investment. These approaches highlight the need for a holistic perspective that considers aspects such as strategy selection, task prioritization, and efficient work order scheduling [22].

In the European university context, facilities maintenance represents the second largest operating cost, ranging from 5% to 15% of the total budget. However, efficiency in the use of these spaces is worryingly low, with utilization rates varying between 20% and 40%. Moreover, the age of many facilities, built in the 1960s and 1970s, presents additional challenges in terms of technical conditions and obsolete designs. Many of these were the subject of study for the application of the so-called total productive maintenance (TPM) [23].

Maintenance is defined as a set of activities performed to preserve or restore an object, infrastructure, or equipment and bring it to a state in which it can perform a certain required task [24]. Maintenance actions are necessary to maintain or improve the quality of a project or service; as a consequence, proper maintenance results in a good project [25], [26]. Inadequate infrastructure and its poor maintenance are characteristic of developing countries. Public infrastructure is fundamental to achieving sustainable development in these nations. In this context, maintenance management takes on great relevance, as it functions as a starting point for improving the quality of the infrastructure. However, these countries must deal with excessive regulatory complexity and permitting processes, which represents an additional challenge [27].

Educational infrastructure goes beyond physical structures; it encompasses a complete ecosystem designed to facilitate the teaching-learning process. It is perceived as a set of spaces that previously needed "to be designed, and then built and equipped, all according to the characteristics of the educational service" [28]. Soto *et al.* [29] points out the importance of considering the functionality of each space and furniture in the design and maintenance of these environments. These spaces not only house educational activities but also directly influence teaching practice and the development of curricular competencies [30], [31]. In sum, the maintenance management of physical infrastructure in educational institutions emerges as a critical factor in the search for educational excellence and sustainable development.

The general objective of this study is to analyze the importance of physical infrastructure maintenance management in educational institutions. Specifically, its implications for educational quality, operational efficiency, and the welfare of the academic community are explored. The central question guiding this research is the following: what is the importance of the maintenance management of physical infrastructure in educational institutions? In addressing this question, the aim is to identify best practices in maintenance management and highlight them as innovative solutions that can be adapted to diverse educational contexts, from rural schools to large university campuses. The ultimate purpose is to describe functional and efficient educational environments that inspire and facilitate learning and innovation for generations to come.

From the perspective of the principle of sustainability, this study presents a novel contribution of a socio-environmental nature, which justifies a systematic review of the advances in the literature related to the management of physical infrastructure maintenance and its possible linkage with the sustainable development goals. This with the purpose of analyzing the contributions in terms of innovation and infrastructure. In this sense, it is essential to determine to what extent structural conditions represent advantages or limitations to ensure inclusive, equitable and quality education, as well as to promote lifelong learning opportunities in healthy environments [32]. All this is intrinsically related to the need for an adequate educational ecosystem, which facilitates the teaching-learning process, favors optimal academic performance and guarantees the safe exercise of the educational function.

2. METHOD

In line with the purpose established for this research, a systematic review of the scientific literature [33] related to the relevance of physical infrastructure maintenance management in educational entities was conducted. The choice of a systematic review is based on its ability to comprehensively identify, evaluate, and synthesize the available empirical evidence. This is possible if pre-established eligibility criteria are met to address a specific research question [34].

This review adhered to the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement, which provides guidelines for optimizing the information search process in systematic reviews and meta-analyses [35]. Additionally, this methodology facilitates the critical evaluation of published systematic reviews. The search procedure was structured in three stages: identification and evaluation of documents, selection, and filtering under predefined criteria, and document analysis. In the initial phase, Scopus, Web of Science (WoS), and ERIC databases were delimited due to their quality guidelines, and relevant sources were selected [36]. The databases were chosen because they include documents directly linked to research lines framed in the social sciences and public administration.

In the second stage, the eligibility criteria [37] were established, limiting the review to publications in both English and Spanish, involving articles of both qualitative and quantitative approaches, research, review, or interventions. Priority was given to articles published in open-access indexed journals, excluding conference papers and doctoral theses. In the second stage, eligibility criteria were established [37], limiting the review to publications in English and Spanish that included articles with qualitative and quantitative approaches, research, review or interventions. Priority was given to articles published in open access indexed journals, and conference papers and doctoral theses were excluded. At this stage, the exclusion criteria were presented, which are detailed in Table 1.

The descriptors selected for this systematic review were "maintenance management", "educational institutions", "public management" and "infrastructure". These terms were combined using the Boolean operators AND-OR, generating the following search formula, as shown in Table 2. Subsequently, the relevance of each study was evaluated for inclusion in the review, according to previously established criteria. As a result of this initial selection phase, 600 documents related to the management of physical infrastructure maintenance in educational institutions were identified, and distributed as: 350 in Scopus, 200 in ERIC, and 50 in WoS.

The preliminary selection of papers was based on title and abstract, followed by a thorough full-text analysis of the shortlisted articles. A 10-year age period, from 2013 to 2023, was initially established to

locate the most recent publications. During the review and tabulation of articles according to their publication date, it was appreciated that the years 2013 and 2014 did not contribute papers, so the interval was reduced to the years 2015 to 2023. The relevant information from each study was extracted and organized in a card that compiled the most significant data according to the established criteria.

Figure 1 shows the process followed for the search of the documents to be examined, which consisted of three specific phases: identification, review and inclusion. In the first phase, 600 records were identified: 350 in the Scopus database, 200 in ERIC and 50 in WoS. A total of 39 duplicates and 86 documents with different subject matter were discarded. In the second stage, the 475 identified papers were reviewed, of which 65 published before 2013 and 122 with restricted access were excluded, resulting in 288 potentially eligible papers. These were examined in detail, resulting in the exclusion of 82 records for not referring to empirical studies, 40 for being in a language other than English or Spanish, and 150 between conference proceedings and theses. Finally, 16 articles were included for the planned systematic analysis.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
- Publications in both English and Spanish	- Articles with incomplete abstract
- Studies with a qualitative and quantitative approach	- Thematic area other than physical infrastructure maintenance management
- Research, review and/or intervention articles	- Publications other than English or Spanish
- Open-access indexed articles in Scopus, and/or WoS, and/or ERIC	- Documents with restricted access
	- Publications before 2013
- Publications from 2013 to 2023	- Do not cite empirical articles
	- Proceedings of congresses or degree theses

Table 2. Search formula according to each database

Database	Language	Search formula
Scopus	English	(Maintenance management AND Public management AND educational institution) OR infrastructure
	Spanish	maintenance management, public management, educational institutions, or infrastructure
WoS	English	(Maintenance management AND Public management AND educational institution) OR infrastructure
	Spanish	maintenance management, public management, educational institutions, or infrastructure
ERIC	English	(Maintenance management AND Public management AND educational institution) OR infrastructure
	Spanish	Maintenance management, public management, and infrastructure

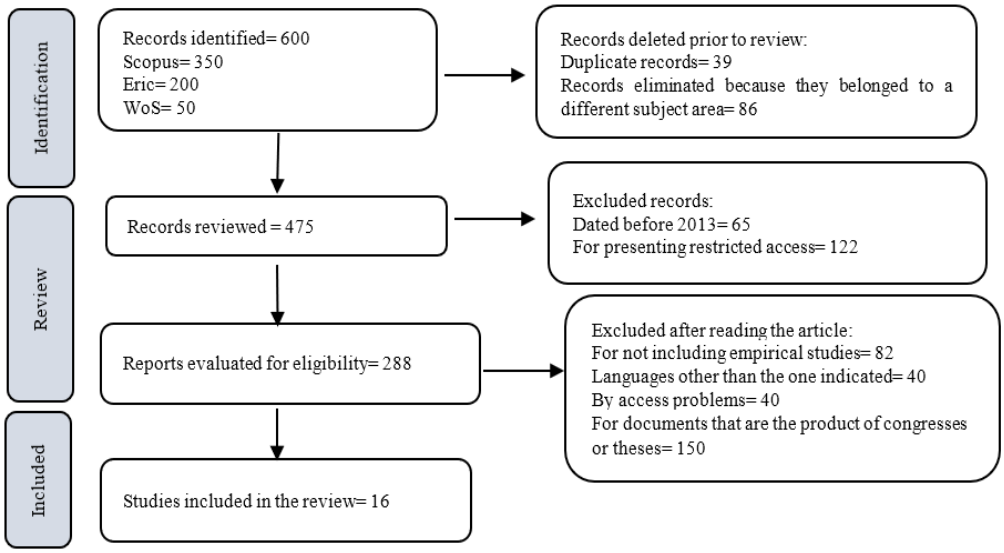

Figure 1. Selection process (PRISMA flowchart)

3. RESULTS AND DISCUSSION

3.1. Results

This systematic literature review reveals significant patterns in the academic production of maintenance management in educational institutions globally. In addition, it identifies practices and challenges faced by such institutions in their relationship to the quality of teaching and learning, as presented in Table 3. Systematic analysis of the papers reviewed provides valuable insights into the publication trends, region, linguistic distribution, and research methodology prevalent in this field of study.

Table 3. Articles included in the review

Ref	Database	Type of study	Region-language	Contributions
[38]	Scopus	Qualitative	Nigeria- English	Universities are critical to the national ability to connect with the new international world and knowledge system. This can be achieved within the scope of an operational facilities management practice. To the extent that the learning environment has been identified as one of the factors that determine effective teaching and learning, deplorable facilities pose a barrier to the achievement of this goal.
[39]	Scopus	Qualitative	Nigeria-English	A digitized framework is needed to provide solutions to the persistent poor maintenance of HEIs buildings. Relevant authorities should address the threat to quality higher education for all, on or before 2030.
[40]	WoS	Qualitative	Australia-English	A considerable lack of investment in maintenance and asset renewal has been recognized as a major challenge in managing public school facilities. Various maintenance strategies have been applied to school infrastructure; however, sufficient funding, well-structured asset management plans, and private sector participation have been identified as essential factors for ensuring successful school infrastructure maintenance.
[41]	Scopus	Qualitative	Italy- English	This study presents a method that utilizes building information modeling (BIM) tools to enhance maintenance processes by increasing efficiency, quality, and speed. The approach integrates building condition assessment (BCA) with BIM to gather, digitize, and assess the physical and performance conditions of assets, aiming to optimize management and maintenance operations.
[42]	Scopus	Quantitative	Croatia - English	The data analysis identified specific deficiencies and issues within the maintenance process. It also indicated that maintenance management lacks full effectiveness. Suggestions were provided to enhance the existing conditions.
[43]	Scopus	Quantitative	Israel- English	The results highlight the need to establish integrated safety and maintenance as a unified approach to enhance advanced maintenance effectiveness and the safety climate in public facility management.
[44]	Scopus	Quantitative	Nigeria-English	Lack of maintenance policy and funding represents the main cause of the damage to public buildings at the University of Nigeria, Nsukka.
[45]	WoS	Quantitative	Brazil-English	The implementation of maintenance plans based on reliability centered maintenance (RCM) has shown potential for enhancing processes by improving service quality and extending the lifespan of process components, ensuring a higher standard of service.
[46]	Scopus	Quantitative	Indonesia- English	This document highlights three essential factors for developing a physical school infrastructure that is inclusive, sustainable, safe, and resilient. These factors include early response funding mechanisms, authentic stakeholder collaboration, and enhanced self-organization capacity.
[47]	Scopus	Quantitative	Italy- English	Spending on school infrastructure increases standardized tests, and math and Italian language scores, and the effect is stronger for lower-performing students and in math.
[48]	ERIC	Qualitative	Nigeria-English	Maintenance culture is seen as the habit, values, and traditions of engaging in those activities designed to repair these facilities, contributing greatly to transforming students' behavior towards school facilities.
[49]	ERIC	Qualitative	Indonesia-English	The development and management of facilities and infrastructure at the International Class Programme (ICP) and the State Institute of Islamic Studies (SIUS) is carried out on the basis of long-term needs, in accordance with the developed master plan, which includes relevant indicators and a comprehensive design of facilities and infrastructure.
[50]	Scopus	Qualitative	Global reach-English	Studies on learning, teaching, and their physical environments can drive meaningful change by offering more defined concepts and a clearer framework for visualization, discussion, and planning.
[51]	Scopus	Quantitative	USA- English	The main contributions of the novel model include an innovative methodology to identify the optimal classification of maintenance activities. In addition, it allows selecting the optimal use of overtime and equipment size for all maintenance activities. Finally, it generates an optimal maintenance schedule that meets practical constraints, such as classroom availability during non-operational hours, and minimizes the total cost of scheduled activities.
[52]	Wos	Qualitative	China- English	The BIM service methodology specification (BIMSM) system was implemented in a university office building in Shanghai, China. This case study achieved 91.6% overall user satisfaction by significantly minimizing space layout errors.
[53]	Scopus	Qualitative	Brazil, Colombia, Cuba, Dominican Republic, Jamaica, and Puerto Rico - English	The panorama of policies, practices, and experiences in South America and the Caribbean is associated with a model based on three pillars for comprehensive school safety.

The distribution of publications by database reflects a clear preference for high impact and international visibility platforms. Of the articles analyzed, 10 were published exclusively in Scopus (63%), 4 in WoS and Scopus (25%), 1 in ERIC and Scopus (6%), and 1 exclusively in ERIC (6%), as displayed in Figure 2. This distribution is evidence of the growing relevance of this topic in the global academic community.

Concerning the place or region where each research project is carried out, the African continent leads in this area, with Nigeria presenting 4 of the 16 publications selected, representing 25% of the total. Indonesia and Italy are in second place, with two publications representing 12.5%. LATAM was present with a study that collectively included countries from South America and the Caribbean, such as Brazil, Colombia, Cuba, Dominican Republic, Jamaica, and Puerto Rico, as shown in Table 4.

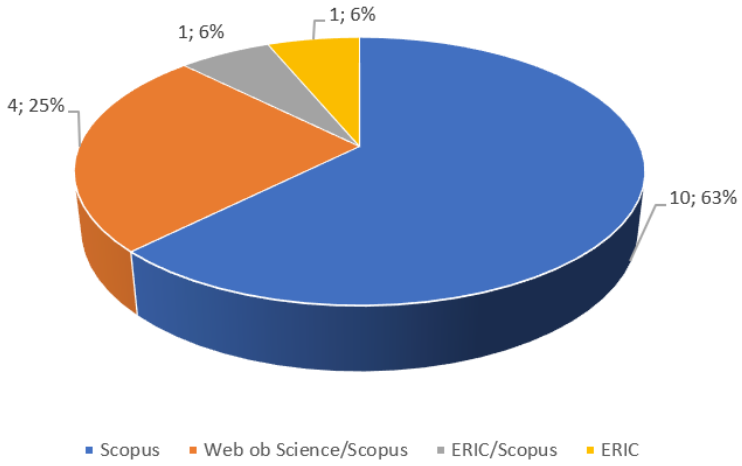

Figure 2. Distribution by database

Table 4. Publications by world region

World region	No. of publications	Percentage (%)
Nigeria	4	25.00
Italy	2	12.50
Indonesia	2	12.50
Brazil	1	6.25
USA	1	6.25
Croatia	1	6.25
Israel	1	6.25
China	1	6.25
Australia	1	6.25
Global reach	1	6.25
South America and the Caribbean	1	6.25
Total	16	100.00

As for the language of publication, English is the predominant language. This prevalence could facilitate greater international dissemination of the findings, but it also raises questions about the accessibility of this information for professionals and decision-makers in contexts where English is not the main language. The methodological analysis reveals a small difference between research approaches, with 9 qualitative and 7 quantitative articles, evidencing a trend toward non-numerical studies, combining perspectives and contexts with generalizable data and values, as presented in Figure 3. This methodological diversity enriches the understanding of the phenomenon studied, providing a holistic view of maintenance management in educational infrastructures.

The temporal distribution of publications shows an increasing trend in recent years, with 31% published in 2022 and 2023, 25% by 2020, as well as 2018 with 6% each, as shown in Figure 4. This increase in recent scholarly output after the drop to 0% in 2021, as an effect of the pandemic, could indicate a growing recognition of the critical importance of educational infrastructure maintenance management. This has likely also been driven by global challenges from the COVID-19 pandemic, which has highlighted the need for safe and well-maintained educational spaces.

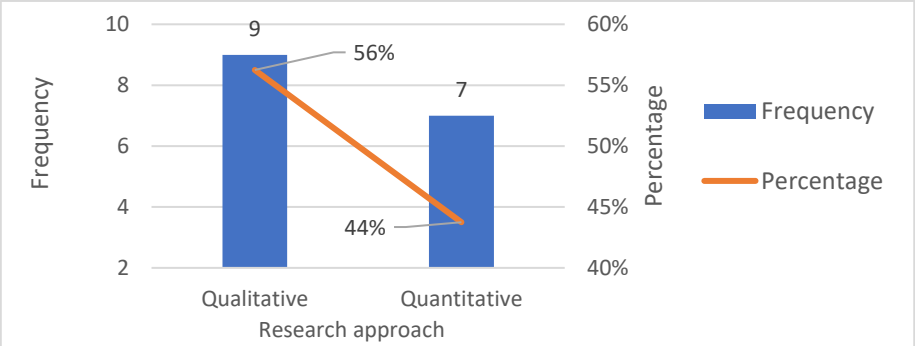

Figure 3. Methodology distribution

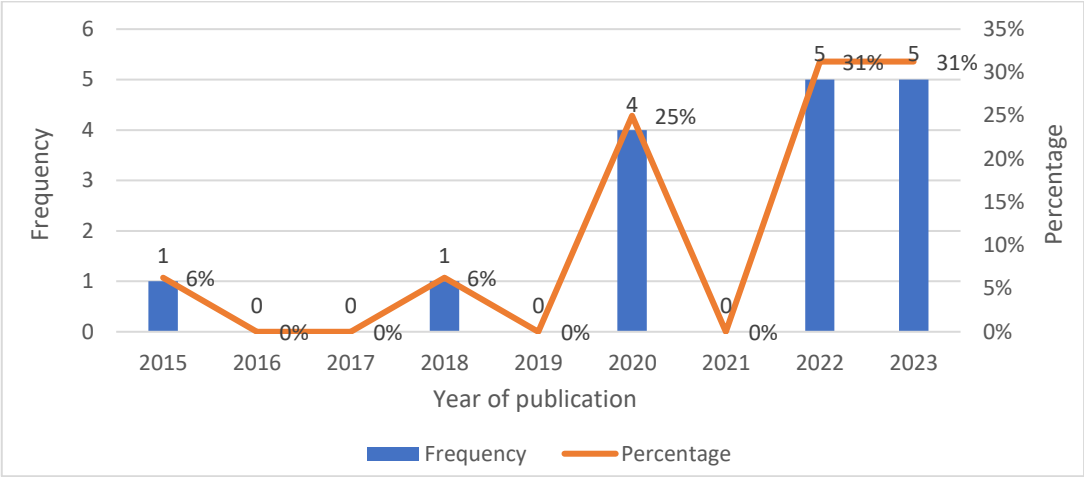

Figure 4. Distribution by year

3.2. Discussion

The analysis of the articles reveals a number of recurring themes and significant findings. Significant underinvestment in maintenance and asset renewal has been identified as one of the main challenges in effective maintenance management in public school facilities. Several studies [38]–[40], [46] highlight the need for adequate funding, sound asset management plans and private sector involvement as key factors for successful infrastructure maintenance in the education sector. They also highlight the importance of implementing digitized frameworks and computerized maintenance management systems to address the persistent problem of equipment and infrastructure availability and efficiency in HEIs.

Similarly, previous studies [36], [42], [47] have explored the relationship between school infrastructure spending and educational outcomes, finding that infrastructure improvements can have a positive impact on academic performance, especially for lower-achieving students. This underlines the importance of investment in educational infrastructure not only for the physical maintenance of facilities, but also as a direct contributor to the quality of education. Likewise, the absence of research related to this topic is of concern, suggesting that this issue has been scarcely addressed in publications indexed in high-impact journals. This is evidence that investment in educational infrastructure is not a priority, leaving many institutions unprepared to respond to current social and technological demands. Consequently, the need for a call for attention to involve local governments in the construction and maintenance of school buildings is evident. This underscores the importance of having sufficient, equitable, and adequate educational infrastructure to meet contemporary demands.

Efficient maintenance management in educational institutions is a fundamental pillar for the achievement of pedagogical objectives and the promotion of an environment conducive to learning. This management encompasses a set of systematic and strategic processes that include the planning, organization, direction, and control of the activities necessary to preserve and optimize the educational physical infrastructure. In agreement with Odediran *et al.* [38], it stresses the imperative need to create safe and comfortable environments that catalyze the acquisition of knowledge by students. This perspective

establishes a clear correlation between the quality of the physical environment and the effectiveness of the learning process. In this way, infrastructure becomes an essential component of the educational equation through efficient maintenance management. In the same context, Arenhart *et al.* [45] support this premise by pointing out that the implementation of actions aimed at improving the availability and performance of facilities strengthens academic results. In addition, reliability centered maintenance (RCM) helps to strengthen the community's bond with the educational institution. The integral conceptualization of maintenance in the educational field transcends the mere conservation of physical structures. Several studies [40], [41], [50] go deeper into this topic, arguing that both infrastructure and furniture are critical elements to achieve the desired educational quality standards. This raises maintenance management and asset renewal as major challenges for the efficient use of resources in public schools. A holistic view of maintenance includes all components of the learning environment, providing a valuable framework for educational managers. In this regard, methods such as BCA combined with BIM, designed to collect, digitize, and assess the physical condition and performance of infrastructure and assets, stand out. However, the lack or deficiency in the implementation of these practices can have negative consequences, as observed in the case of Nigeria. Assaad *et al.* [2] assert that the deterioration of physical facilities directly affects the satisfaction of educational needs and functional learning.

A recurrent and alarming finding in the literature reviewed is the widespread prevalence of significant deficiencies in the maintenance and upkeep of school buildings [51], [52]. The persistence of this problem across diverse geographical and temporal contexts suggests the existence of a systemic challenge. According to this, it demands a paradigm shift in the conceptualization and prioritization of educational infrastructure maintenance at the global level, implementing many actions in this regard. Among them we have, for example, an optimal maintenance program that meets all practical constraints, availability of classrooms during their non-operational hours, and minimizing the total maintenance cost of all scheduled activities. It is here where the BIMSM allows to improve the use of educational spaces.

The discrepancy between the existing legal frameworks in LATAM and reality indicates that the practice of maintenance of educational infrastructure is a significant obstacle. Wang *et al.* [43] emphasize that integrated security and maintenance should be implemented as a unified procedure before a detailed analysis of the observed situation. This should be subject to the constitutions and educational policies of various LATAM countries to nominally recognize the importance of educational infrastructure. However, this legal rhetoric contrasts sharply with the reality observed on the ground, revealing a substantial gap between policy intentions and actual implementation. This disparity is most pronounced in rural areas, where the quality and quantity of educational infrastructure is markedly below the world average, perpetuating and aggravating existing educational inequalities.

In the field of evaluation and maintenance of educational buildings, the imperative need to establish adequate criteria and effective strategies emerges. The research by Opabola [46] and Mormah [48] agree with Wang and Yin [5], who emphasize the criticality of this aspect in quality control and building recovery. Similarly, research on an integrated maintenance approach is of great relevance in the educational field. This methodology encompasses the classification of maintenance activities, the optimization of human and time resources, and the development of maintenance schedules that address operational constraints [43], [49].

The implications derived from this review are multifaceted and far-reaching for educational policy formulation and institutional management. The imperative need for governments and educational institutions to categorically prioritize infrastructure maintenance in their budget allocations and strategic planning becomes apparent [44]. Likewise, this entails a fundamental paradigm shift, conceiving maintenance not as an expense, but as a crucial investment in educational quality and the integral well-being of the academic community [46], [47]. It is necessary to adopt a holistic approach that integrates maintenance management as a fundamental component of educational quality, transcending its perception as a mere logistical or administrative aspect. This position is supported by Vidal-Chamorro *et al.* [15], who argue that efficient resource management favors the well-being of the population and promotes integral development.

The formation of human capital specialized in educational infrastructure maintenance management emerges as a pressing need. This could be materialized through specific training programs, the exchange of best practices among institutions, and the creation of dedicated roles within educational administrative structures. In parallel, the adoption of innovative technologies and methodologies can significantly boost maintenance efficiency [39], [42]. This could include the implementation of computer-aided maintenance management systems. These rely on the digitization of information, real-time monitoring technologies, and predictive approaches to anticipate and prevent maintenance problems.

Community involvement is emerging as a potentially effective strategy for maximizing limited resources. As noted by previous researchers [43], [44], it is important to involve students, parents, and community members in the basic care and maintenance of facilities can not only reduce costs but also foster a sense of shared ownership and responsibility for the educational infrastructure. Finally, it is imperative to implement robust monitoring and evaluation systems to ensure the effectiveness of maintenance strategies.

This involves establishing clear performance indicators, conducting periodic evaluations, and using the results to inform and continually adjust maintenance practices.

Muñoz *et al.* [53] emphasize that efficient management of physical infrastructure maintenance is key to ensuring educational quality in LATAM. This is particularly crucial in resource-constrained environments, such as those prevailing in the region. However, geopolitical conditions generate a particular scenario in South America and the Caribbean, associated with a model based on three pillars of comprehensive school safety. First, the focus on safe learning facilities; second, school disaster management; and finally, risk reduction through resilience education. This model seeks to address emerging challenges, such as budgetary constraints, lack of political prioritization, and deficiencies in technical capacity. Despite these difficulties, the literature proposes promising guidelines that offer sustainable solutions [5].

A multidimensional and synergistic approach is required that combines appropriate policies, sustained investment, management innovation, and community participation. This approach seeks to significantly improve learning conditions in educational institutions. A holistic approach not only has the potential to improve educational outcomes, but also contributes to educational equity. This translates into dignified and stimulating learning environments for all students, regardless of their geographical location or socio-economic background.

4. CONCLUSION

The analysis of maintenance management in educational infrastructure reveals its decoupling from the sustainable development goals, which calls for an intervention aligned with the 2030 agenda. To ensure sustainability and learning in safe environments, planned and monitored maintenance that optimizes academic performance is essential. Effective and reliable management can prevent risks before they become serious problems that affect safety and educational development. Therefore, government decision makers must implement public policies that identify weaknesses and prevent infrastructure failures.

These policies should include continuous maintenance and modernization of management at all levels of government, with tools that enable efficient supervision. To improve sustainability, responsible institutions should implement automated systems that optimize maintenance execution, better allocate resources, and streamline response to emerging needs. In addition, future research can analyze the long-term impact of various maintenance strategies in educational institutions, including comparative studies between different national and regional contexts to identify good practices. Finally, it is key to broaden the research approach and incorporate evaluations of the economic and social impact of investment in educational infrastructure.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Julisa del Rosario Quispe Vilca	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	
Dennys Geovanni Calderón Paniagua	✓	✓				✓		✓	✓	✓	✓	✓		
Grisely Rosalie Quispe Vilca	✓	✓		✓	✓	✓		✓	✓		✓			
Isabel Evelyna Choque Siguairo	✓	✓		✓	✓	✓				✓	✓			
Alexander Nicolás Vilcanqui Alarcón	✓	✓			✓	✓				✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] M. Ahmad, "Management of facilities and infrastructure in schools," *Akademika*, vol. 10, no. 1, pp. 93–112, May 2021, doi: 10.34005/akademika.v10i01.1348.

[2] R. H. Assaad, G. Assaf, and M. Boufadel, "Optimizing the maintenance strategies for a network of green infrastructure: An agent-based model for stormwater detention basins," *Journal of Environmental Management*, vol. 330, p. 117179, Mar. 2023, doi: 10.1016/j.jenvman.2022.117179.

[3] M. del C. Olmos-Gómez, M. L. Suárez, C. Ferrara, and E. M. Olmedo-Moreno, "Quality of higher education through the pursuit of satisfaction with a focus on sustainability," *Sustainability*, vol. 12, no. 6, p. 2366, Mar. 2020, doi: 10.3390/su12062366.

[4] A. A. Adangabe, H. D. Adzakpa, N. Freeman, K. Kudzawu, and G. A. Adangabey, "Infrastructural maintenance practices in schools and its impact on education delivery in Ghana: the case of selected schools in the build south district," *International Journal of Psychology and Education*, vol. 4, pp. 93–104, 2020.

[5] M. Wang and X. Yin, "Construction and maintenance of urban underground infrastructure with digital technologies," *Automation in Construction*, vol. 141, p. 104464, Sep. 2022, doi: 10.1016/j.autcon.2022.104464.

[6] S. Farmer and R. Weber, "Education reform and financialization: making the fiscal crisis of the schools," *International Journal of Urban and Regional Research*, vol. 46, no. 6, pp. 911–932, Nov. 2022, doi: 10.1111/1468-2427.13137.

[7] K. Okoye *et al.*, "Impact of digital technologies upon teaching and learning in higher education in Latin America: an outlook on the reach, barriers, and bottlenecks," *Education and Information Technologies*, vol. 28, no. 2, pp. 2291–2360, Feb. 2023, doi: 10.1007/s10639-022-11214-1.

[8] United States Government Accountability Office, "K-12 Education school districts frequently identified multiple building systems needing updates or replacement," 2020. [Online]. Available: https://www.gao.gov/assets/gao-20-494.pdf

[9] M. H. Fernandez-Fuentes, A. A. Eras-Almeida, and M. A. Egido-Aguilera, "Characterization of technological innovations in photovoltaic rural electrification, based on the experiences of Bolivia, Peru, and Argentina: Third generation solar home systems," *Sustainability*, vol. 13, no. 6, p. 3032, Mar. 2021, doi: 10.3390/su13063032.

[10] Ministerio de Educación, "Plan Nacional De Infraestructura Educativa Al 2025– Minedu." 2017. [Online]. Available: https://siteal.iiep.unesco.org/sites/default/files/sit_accion_files/plan_nacional_de_infraestructura_educativa_al_2025.pdf

[11] C. Sanchís-Pedregosa, J. M. Vizcarra-Aparicio, and A. L. Leal-Rodríguez, "BIM: a technology acceptance model in Peru," *Journal of Information Technology in Construction*, vol. 25, pp. 99–108, Feb. 2020, doi: 10.36680/j.itcon.2020.006.

[12] V. Klochan, I. Piliaiev, T. Sydorenko, V. Khomutenko, A. Solomko, and A. Tkachuk, "Digital platforms as a tool for the transformation of strategic consulting in public administration," *Journal of Information Technology Management*, vol. 13, pp. 42–61, 2021, doi: 10.22059/JITM.2021.80736.

[13] J. Ozga, "The politics of accountability," *Journal of Educational Change*, vol. 21, no. 1, pp. 19–35, Feb. 2020, doi: 10.1007/s10833-019-09354-2.

[14] X. B. Martínez, "Postmodernity, public management and information and communication technologies in the Public Administration of Ecuador," *Estado & comunes, revista de políticas y problemas públicos*, vol. 1, no. 14, pp. 113–131, Jan. 2022, doi: 10.37228/estado_comunes.v1.n14.2022.244.

[15] R. I. Vidal-Chamorro, C. P. Martel-Carranza, and N. Z. T.-S. de Martel, "Public management and the results-based budget of the Dirección Regional de Educación Huánuco," *Gaceta Científica*, vol. 7, no. 3, pp. 115–120, 2021.

[16] E. Kang, "Whose money matters in public education: A 'public' good that parents purchase," *Policy Futures in Education*, vol. 20, no. 8, pp. 960–985, Nov. 2022, doi: 10.1177/14782103211034348.

[17] T. Klenk and R. Reiter, "Post-New Public Management: reform ideas and their application in the field of social services," *International Review of Administrative Sciences*, vol. 85, no. 1, pp. 3–10, Mar. 2019, doi: 10.1177/0020852318810883.

[18] A. Castanedo, Abay, "Social development, public management and the New Face of Global Public Administration," (in Spanish), *Revista Estudios del Desarrollo Social: Cuba y América Latina*, vol. 10, no. 2, pp. 1–18, 2022. [Online]. Available: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2308-01322022000200005&lng=es&nrm=iso&tlng=es%0Ahttp://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S2308-01322022000200005&lng=es&nrm=iso&tlng=es

[19] C. Ansell, E. Sørensen, and J. Torfing, "Public administration and politics meet turbulence: The search for robust governance responses," *Public Administration*, vol. 101, no. 1, pp. 3–22, Mar. 2023, doi: 10.1111/padm.12874.

[20] Y. J. Lu, W. C. Lee, and C. H. Wang, "Using data mining technology to explore causes of inaccurate reliability data and suggestions for maintenance management," *Journal of Loss Prevention in the Process Industries*, vol. 83, p. 105063, Jul. 2023, doi: 10.1016/j.jlp.2023.105063.

[21] Z. Ma, Y. Ren, X. Xiang, and Z. Turk, "Data-driven decision-making for equipment maintenance," *Automation in Construction*, vol. 112, p. 103103, Apr. 2020, doi: 10.1016/j.autcon.2020.103103.

[22] P. Longart, "Understanding hotel maintenance management," *Journal of Quality Assurance in Hospitality and Tourism*, vol. 21, no. 3, pp. 267–296, May 2020, doi: 10.1080/1528008X.2019.1658148.

[23] P. Poór, D. Ženíšek, and J. Basl, "Historical overview of maintenance management strategies: Development from breakdown maintenance to predictive maintenance in accordance with four industrial revolutions," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2019, pp. 495–504.

[24] M. I. Adegoriola, J. H. K. Lai, E. H. Chan, and D. Amos, "Heritage building maintenance management (HBMM): A bibliometric-qualitative analysis of literature," *Journal of Building Engineering*, vol. 42, Oct. 2021, doi: 10.1016/j.jobe.2021.102416.

[25] R. M. Pavón, A. A. Arcos Alvarez, and M. G. Alberti, "BIM-based educational and facility management of large university venues," *Applied Sciences*, vol. 10, no. 22, p. 7976, Nov. 2020, doi: 10.3390/app10227976.

[26] A. Amir and M. Henry, "Reverse engineering of maintenance budget allocation using decision tree analysis for data-driven highway network management," *Sustainability*, vol. 15, no. 13, p. 10467, Jul. 2023, doi: 10.3390/su151310467.

[27] E. N. K. Nkrumah, T. Stephen, L. Takyi, and O. A. Anaba, "Public infrastructure maintenance practices in Ghana," *Review of Public Administration and Management*, vol. 5, no. 3, p. 234, 2017, doi: 10.4172/2315-7844.1000234.
[28] J. R. Ruiz-Sarmiento, J. Monroy, F. A. Moreno, C. Galindo, J. M. Bonelo, and J. Gonzalez-Jimenez, "A predictive model for the maintenance of industrial machinery in the context of industry 4.0," *Engineering Applications of Artificial Intelligence*, vol. 87, p. 103289, Jan. 2020, doi: 10.1016/j.engappai.2019.103289.
[29] B. G. de Soto, A. Georgescu, B. Mantha, Ž. Turk, A. Maciel, and M. S. Sonkor, "Construction cybersecurity and critical infrastructure protection: new horizons for Construction 4.0," *Journal of Information Technology in Construction*, vol. 27, pp. 571–594, Jun. 2022, doi: 10.36680/j.itcon.2022.028.
[30] S. Ait-Lamallam, R. Yaagoubi, I. Sebari, and O. Doukari, "Extending the IFC standard to enable road operation and maintenance management through openBIM," *ISPRS International Journal of Geo-Information*, vol. 10, no. 8, p. 496, Jul. 2021, doi: 10.3390/ijgi10080496.
[31] P. Larsson and J. Löwstedt, "Distributed school leadership: Making sense of the educational infrastructure," *Educational Management Administration and Leadership*, vol. 51, no. 1, pp. 138–156, 2023, doi: 10.1177/1741143220973668.
[32] G. C. Ozoagu and N. Oliver, "Managing school plant for the achievement of sustainable development goals (SDGs): the Proactivity of Education for all in Enugu State," *ESUT Journal of Education*, vol. 6, no. 1, pp. 111–119, 2023.
[33] J. A. A. Damen, K. G. M. Moons, M. van Smeden, and L. Hooft, "How to conduct a systematic review and meta-analysis of prognostic model studies," *Clinical Microbiology and Infection*, vol. 29, no. 4, p. 434, 2023, doi: 10.1016/j.cmi.2022.07.019.
[34] L. Uttley *et al.*, "The problems with systematic reviews: a living systematic review," *Journal of Clinical Epidemiology*, vol. 156, pp. 30–41, Apr. 2023, doi: 10.1016/j.jclinepi.2023.01.011.
[35] P. C. Sauer and S. Seuring, "How to conduct systematic literature reviews in management research: a guide in 6 steps and 14 decisions," *Review of Managerial Science*, vol. 17, no. 5, pp. 1899–1933, Jul. 2023, doi: 10.1007/s11846-023-00668-3.
[36] G. Escalante, R. Loaiza-Carrasco, F. Barriga, R. Jiménez, and H. Barriga, "Research management in University Education: bibliometric and systematic review," *Nanotechnology Perceptions*, vol. 20, no. 11, pp. 822–840, 2024.
[37] Q. Su, G. Cheng, and J. Huang, "A review of research on eligibility criteria for clinical trials," *Clinical and Experimental Medicine*, vol. 23, no. 6, pp. 1867–1879, Jan. 2023, doi: 10.1007/s10238-022-00975-1.
[38] S. J. Odediran, J. T. Gbadegesin, and M. O. Babalola, "Facilities management practices in the Nigerian public universities," *Journal of Facilities Management*, vol. 13, no. 1, pp. 5–26, Feb. 2015, doi: 10.1108/JFM-11-2013-0058.
[39] A. Ebekozien, C. Aigbavboa, M. S. Samsurijan, M. I. Rohayati, and N. M. Malek, "Developing a framework for higher education institution building maintenance via soft system methodology," *International Journal of Building Pathology and Adaptation*, vol. 41, no. 6, pp. 184–200, Dec. 2023, doi: 10.1108/IJBPA-03-2023-0030.
[40] N. Herath, C. Duffield, and L. Zhang, "Public-school infrastructure ageing and current challenges in maintenance," *Journal of Quality in Maintenance Engineering*, vol. 29, no. 2, pp. 401–419, Apr. 2023, doi: 10.1108/JQME-06-2021-0043.
[41] A. Salzano, C. M. Parisi, G. Acampa, and M. Nicolella, "Existing assets maintenance management: Optimizing maintenance procedures and costs through BIM tools," *Automation in Construction*, vol. 149, May 2023, doi: 10.1016/j.autcon.2023.104788.
[42] K. T. Štrok, S. Marenjak, and D. Car-Pušić, "Analysis of the current maintenance management process in school buildings: study Area of Primorje-Gorski Kotar County, Republic of Croatia," *Frontiers in Built Environment*, vol. 8, p. 912326, May 2022, doi: 10.3389/fbuil.2022.912326.
[43] K. C. Wang, R. Almassy, H. H. Wei, and I. M. Shohet, "Integrated building maintenance and safety framework: educational and public facilities case study," *Buildings*, vol. 12, no. 6, p. 770, Jun. 2022, doi: 10.3390/buildings12060770.
[44] O. O. Ugwu, C. C. Okafor, and C. U. Nwoji, "Assessment of building maintenance in Nigerian university system: a case study of University of Nigeria, Nsukka," *Nigerian Journal of Technology*, vol. 37, no. 1, pp. 44–52, Jan. 2018, doi: 10.4314/njt.v37i1.6.
[45] R. S. Arenhart, M. Pizzolato, A. A. Mendes, and L. Braghirolli, "Contribution evaluation of the maintenance plans based on reliability centered maintenance for measuring instruments in Public Higher Education Institutions," *Brazilian Journal of Operations and Production Management*, vol. 17, no. 2, p. e2020873, Jun. 2020, doi: 10.14488/BJOPM.2020.020.
[46] E. A. Opabola, C. Galasso, T. Rossetto, E. Meilianda, Y. Idris, and S. Nurdin, "Investing in disaster preparedness and effective recovery of school physical infrastructure," *International Journal of Disaster Risk Reduction*, vol. 90, p. 103623, May 2023, doi: 10.1016/j.ijdrr.2023.103623.
[47] A. Belmonte, V. Bove, G. D'Inverno, and M. Modica, "School infrastructure spending and educational outcomes: Evidence from the 2012 earthquake in Northern Italy," *Economics of Education Review*, vol. 75, p. 101951, Apr. 2020, doi: 10.1016/j.econedurev.2019.101951.
[48] F. Mormah, "The management and maintenance of physical facilities for quality assurance in higher education in the 21st century with innovative technologies," *African Educational Research Journal*, vol. 11, no. 2, pp. 220–224, May 2023, doi: 10.30918/aerj.112.23.008.
[49] S. Famularsih, A. Nuryatin, E. Handoyo, and S. W. Fitriati, "Facility and infrastructure management at the international class program of the state islamic university in Indonesia," *Journal of Social Studies Education Research*, vol. 13, no. 4, pp. 291–307, 2022.
[50] P. Goodyear, "Realising the Good University: Social innovation, care, design justice and educational infrastructure," *Postdigital Science and Education*, vol. 4, no. 1, pp. 33–56, Jan. 2022, doi: 10.1007/s42438-021-00253-5.
[51] M. Alashari, K. El-Rayes, and M. AlOtaibi, "Optimizing the planning of maintenance activities in education buildings," *Journal of Construction Engineering and Management*, vol. 149, no. 10, p. 04023094, Oct. 2023, doi: 10.1061/jcemd4.coeng-13215.
[52] G. Ma, X. Song, and S. Shang, "BIM-based space management system for operation and maintenance phase in educational office buildings," *Journal of Civil Engineering and Management*, vol. 26, no. 1, pp. 29–42, Dec. 2020, doi: 10.3846/jcem.2019.11565.
[53] V. A. Muñoz *et al.*, "Success, innovation and challenge: School safety and disaster education in South America and the Caribbean," *International Journal of Disaster Risk Reduction*, vol. 44, p. 101395, Apr. 2020, doi: 10.1016/j.ijdrr.2019.101395.

BIOGRAPHIES OF AUTHORS

Julisa del Rosario Quispe Vilca is a civil engineer and master's in Civil Engineering with a mention in Construction Management from Universidad Privada de Tacna. Master's in public management from Universidad César Vallejo, with extensive professional experience in the construction sector and the development of research articles related to civil engineering. She can be contacted at email: julisa.qv@hotmail.com.

Dennys Geovanni Calderón Paniagua is a civil engineer and lawyer, licensed and authorized. Master's in civil engineering with a mention in Construction Management. Master's in public management and governance; Doctor in Administration; Graduate of the Program of Updating and Application of Governmental Control and the Teacher Training Program of the National School of Control of the General Controller's Office of the Republic. Speaker in several regional, national, and international congresses. Advisor on research on issues of administration, quality of service, social control, law, public management, civil engineering, management of participation and citizen control, and transparency of information. He has accredited intellectual production in research articles and books. Professional with capacity for entrepreneurship, initiative, and leadership; honest and creative. He can be contacted at email: dcalderonp@unjbg.edu.pe.

Grisely Rosalie Quispe Vilca is a commercial engineer. Master's in business administration and management, MBA and PhD in Administration; Specialist of the Ministry of Women and Vulnerable Populations; University professor with undergraduate experience at Universidad Nacional Mayor de San Marcos (UNMSM), Universidad Nacional Jorge Basadre Grohmann (UNJBG) in Tacna, Peru, and Universidad José Carlos Mariátegui (UJCM) in Moquegua, Peru. She has postgraduate experience at Universidad César Vallejo (UCV). She has a capacity for entrepreneurship and initiative, leadership, creativity, and solid training in values, as well as extensive technical and administrative experience in public and private institutions, and the exercise of university teaching, consulting, and research. She is a Concytec researcher. She can be contacted at email: gquispev@unjbg.edu.pe.

Isabel Evelyna Choque Siguairo had a degree in Social Communication with a major in Journalism and Public Relations from Universidad Nacional Jorge Basadre Grohmann; Master's in public management from Universidad César Vallejo. Currently, she teaches at the Universidad Privada de Tacna. She has extensive experience in university teaching. She can be contacted at email: alexandra_tc2@outlook.com.ar.

Alexander Nicolás Vilcanqui Alarcón is a civil Engineer from the Universidad Privada de Tacna. Master of Science in Environmental Management and Sustainable Development; Doctor in Environmental Sciences from Universidad Nacional Jorge Basadre Grohmann. Professional with extensive experience in the construction sector and the exercise of university teaching, as well as in the development of research related to civil engineering. He can be contacted at email: C25841@utp.edu.pe.