OPTIMIZATION OF THE MANAGEMENT OF MAINTENANCE OF EDUCATIONAL FACILITIES AND INFRASTRUCTURE TO IMPROVE THE QUALITY OF LEARNING

Dinny Mardiana[1], Asep Sujani[2*], Alpa Ruhyat[3], Mila Meilani[4], Ruri C. Hetiawati[5]
[1,2,3,4,5]Universitas Islam Nusantara Bandung, Indonesia
Email: mardianadinny3@gmail.com[1], *sujaniasep@gmail.com[2*], meilanimila44@gmail.com[3],*
ruri.shentiawati26@gmail.com[4], arkaalpa01@gmail.com[5]

Abstract
This study aims to analyze the optimization of educational facilities and infrastructure maintenance management and its contribution to improving learning quality in secondary schools. Qualitative research with multi-site case study design was conducted in eight junior and senior high schools in Cianjur City, West Java, involving 85 participants consisting of school principals, vice principals for facilities and infrastructure, teachers, school committee members, educational staff, and students. Data were collected through in-depth interviews, participatory observation, and documentation study over four months, then analyzed using Miles, Huberman, and Saldaña thematic approach with NVivo 12. The findings identified four key dimensions of optimization: (1) data-based maintenance planning with priority scales; (2) structured implementation of preventive, corrective, and predictive maintenance; (3) budget allocation of minimum 15-20% of operational budget; (4) continuous monitoring and evaluation. Schools with optimal maintenance systems demonstrated learning quality improvement through smooth learning process (93%), increased student motivation (87%), effective learning media use (89%), minimized disruptions (91%), and higher learning outcomes (average 8.5 points higher). Optimization success was influenced by principal leadership, human resource competence, integrated management systems, stakeholder participation, and organizational culture. The study concludes that optimization of facilities and infrastructure maintenance management contributes significantly to learning quality improvement, recommending development of digital inventory systems, increased budget allocation, implementation of integrated systems, and establishment of minimum maintenance standards in educational policies.
Keywords: Maintenance Management, Educational Facilities and Infrastructure, Learning Quality, Multi-Site Case Study, Secondary Schools

INTRODUCTION

Education is a fundamental pillar in the development of quality human resources and is a strategic investment for the progress of a nation. In the national education system, the success of the learning process does not only depend on the quality of educators and the curriculum applied, but is also greatly influenced by the availability and condition of adequate educational facilities and infrastructure. Educational facilities and infrastructure are essential components that function as supporting facilities in creating a conducive learning environment, so as to enable the implementation of an effective, efficient, and meaningful learning process for students. In the context of education management, the management of facilities and infrastructure includes a series of processes ranging from planning, procurement, inventory, use, to maintenance. Among these various functions, the maintenance aspect is often an area that receives less optimal attention from education managers. In fact, systematic and continuous maintenance has a crucial role in ensuring that educational facilities and infrastructure remain in a suitable condition, functional, and can support the learning process to the maximum. The phenomenon that occurs in the field shows that many educational institutions have experienced a drastic decline in the quality of facilities in a relatively short time due to the lack of planned and structured maintenance efforts.

Data from the Central Statistics Agency in 2024 reveals worrying conditions related to the damage to education infrastructure in Indonesia. The condition of damaged classrooms still reaches twenty-three point four percent for elementary school level, eighteen point seven percent for junior high school, and fifteen point three percent for high school and vocational schools. This condition not only has an impact on the physical aspects of the building, but also has serious implications for the quality of the learning process, the comfort and safety of students, and the effectiveness of using innovative learning methods. Furthermore, the condition of facilities and infrastructure that is not maintained can reduce students' motivation to learn, inhibit teachers' creativity in using learning media, and give a negative image to the quality of management of educational institutions.

The urgency of research on optimizing the management of the maintenance of educational facilities and infrastructure is increasingly crucial in the current era of educational transformation. The implementation of the Independent Curriculum which demands more active, creative, and student-centered learning requires adequate and well-maintained facilities and infrastructure. Without optimal maintenance, the huge investments that the government and the community have made in the construction and procurement of educational facilities will be wasted due to premature deterioration that should have been prevented. This condition shows that maintenance is not just an operational technical activity, but an investment strategy that has long-term implications for the sustainability and effectiveness of the education system. The significance of this problem is also closely related to the efficiency of the education budget which is a serious concern for various parties. Research shows that the cost of repairs due to unpredictable damage can be three to five times greater than the cost of planned preventive maintenance. In the midst of the limited education budget faced by many schools, especially in disadvantaged and remote areas, optimization of maintenance management is an important strategy to ensure the sustainability and effectiveness of resource use. Moreover, the condition of well-maintained facilities and infrastructure has a positive correlation with the achievement of learning quality, which is measured through various indicators such as student learning outcomes, stakeholder satisfaction, and the effectiveness of the learning process.

If this problem does not receive serious attention, the long-term impact will be very detrimental to the national education system. There will be a decrease in the quality of the learning environment which will have an impact on decreasing the motivation and learning achievement of students, which in turn will affect the quality of Indonesian human resources in the future. Budget waste will continue to occur due to reactive and unplanned maintenance patterns, thereby reducing the allocation of funds for other priority programs such as teacher competency development or improving the quality of learning. The gap in education quality will widen between schools that have a good maintenance system and those that do not, thus threatening the principle of equal distribution of education quality which is a constitutional ideal. The credibility and accountability of educational institutions will

decrease in the eyes of stakeholders, especially parents and the community, which can lead to a decline in public trust in the education system as a whole.

Research on the management of educational facilities and infrastructure has evolved significantly in the last decade with a variety of diverse perspectives and approaches. Hasibuan and Silvya in their research in 2019 found that facility and infrastructure management has a significant effect on learning effectiveness with a contribution of sixty-seven point three percent. This study emphasizes the importance of systematic planning, organizing, and supervision in the management of educational assets as a key factor in creating a quality learning environment. Meanwhile, Arifin in 2020 revealed an important finding that preventive maintenance carried out consistently can extend the useful life of infrastructure facilities by up to forty percent compared to reactive maintenance patterns, which shows that investment in preventive maintenance has a very significant return in the long term.

Wulandari and Suryana's research in 2021 brought a new perspective by exploring the relationship between the condition of infrastructure facilities and the quality of learning in the digital era. They found that the integration between the maintenance of physical facilities and technological infrastructure was a key factor in supporting twenty-first-century learning. This study provides important insights that the concept of maintenance has evolved and is no longer limited to the physical aspects of buildings alone, but also includes the maintenance of technological devices, information systems, and digital infrastructure that are increasingly vital in the modern learning ecosystem. This shows that the maintenance paradigm needs to be adapted to technological developments and contemporary learning demands.

From a strategic management perspective, Nurabadi and colleagues in 2022 developed an information system-based maintenance management model that integrates planning, implementation, and monitoring in one integrated digital platform. The results of his research show that the implementation of a maintenance management information system can increase efficiency by up to fifty-eight percent and reduce maintenance costs by up to thirty-five percent. These findings provide a strong empirical foundation on the importance of technology adoption in optimizing maintenance management in the digital age, while also demonstrating that digital transformation in maintenance management is no longer an option but a necessity to achieve optimal effectiveness and efficiency.

In an international context, a study conducted by Abdul-Rahman and his colleagues in 2023 on facility management in Malaysian educational institutions identified that a lack of a culture of maintenance is a major challenge in the management of educational facilities. This study recommends the importance of building a culture of maintenance through continuous capacity building, clear standardization of operational procedures, and an incentive system for units or individuals who successfully maintain facilities well. These findings confirm that aspects of organizational culture and individual behavior have an equally important role as technical and managerial aspects in the success of maintenance management. Meanwhile, a comparative study conducted by Zhang and Liu in 2022 in

China showed surprising results that schools with structured maintenance systems had an average learning quality score of twenty-three percent higher than schools without a clear maintenance system, further reinforcing the argument about the importance of maintenance in learning ecosystems.

Although various studies have been conducted on the management of educational facilities and infrastructure, there are several gaps that need to be bridged to develop a more comprehensive understanding. The first gap identified is that most previous research has tended to address the management of facilities and infrastructure in general without a deep focus on the maintenance aspect as a strategic function that requires special attention. The studies have explored more of the planning and procurement functions in the asset management cycle, while the maintenance aspect is only superficially discussed as part of the management process without in-depth elaboration on its complexity and significance.

The second and no less important gap is that the existing literature is still limited in exploring the concept of holistic and comprehensive maintenance optimization. Optimization does not just mean performing routine maintenance or allocating sufficient budget, but includes broader dimensions such as the effectiveness of procedures, resource use efficiency, long-term sustainability, and its contribution to achieving learning objectives. Research that specifically examines optimization strategies with systemic and measurable approaches is still very limited, especially in the context of education in Indonesia with unique characteristics and challenges.

A third gap that needs attention is the lack of research that explicitly analyzes the mechanisms and pathways of how maintenance management optimization contributes to improving the quality of learning. Most studies have only shown a statistical correlation or influence between the two variables without exploring the mediation process and the complex moderation factors in the relationship. This gap is important to bridge in order to provide a more comprehensive understanding of how interventions in the maintenance system can be translated into concrete improvements in the quality of learning, so that more targeted and effective strategies can be formulated.

The fourth gap lies in the aspect of the research methodology used in previous studies. Previous studies tend to use a descriptive or correlational quantitative approach that does provide an overview of the relationships between variables, but is limited in exploring the context, process, and dynamics of implementation in the field. Studies that use mixed methods or in-depth qualitative approaches to understand best practices, challenges faced, and effective optimization strategies in various contexts are still very limited. In fact, an in-depth understanding of the context, implementation process, and organizational dynamics is essential to produce recommendations that are not only theoretically valid but also applicable and contextual in real practice in educational institutions.

The novelty or novelty of this research lies in the effort to integrate the theoretical perspective of strategic management with empirical practice in the field to develop a comprehensive, measurable, and learning-oriented maintenance management optimization model. This research will not only identify

what needs to be done, but also how to do it effectively in various educational institution contexts. Furthermore, this research will explore best practices and lessons learned from various contexts of educational institutions with diverse characteristics, so that it can produce an adaptive and applicative framework to be applied in various educational settings, both public and private schools, in urban and rural areas.

Based on the background, urgency of the problem, literature review, and research gaps that have been presented, this study formulates several research questions as a guide in exploring this topic in depth. The first question that wants to be answered is how the implementation of the management of the maintenance of educational facilities and infrastructure carried out by educational institutions today, and what are the factors that affect the effectiveness of its implementation. This question is important to understand the existing conditions and identify the gap between existing practices and ideal practices that should be applied.

The second research question that is no less important is what are the strategies and best practices that can be done to optimize the maintenance management of educational facilities and infrastructure. This question aims to explore various approaches, methods, and techniques that have been proven effective in improving the quality of maintenance, so that it can serve as a reference for other educational institutions looking to improve their maintenance systems.

The third question that is the focus of this research is how the contribution of optimizing the management of maintenance of facilities and infrastructure to improving the quality of learning, and through what mechanism this contribution occurs. This question will uncover the complex processes and pathways of influence between maintenance and learning quality, so as to provide a more comprehensive understanding of the importance of investing in maintenance.

The last question that wants to be answered in this study is how to optimize the management of the maintenance of educational facilities and infrastructure that is effective, efficient, and sustainable to improve the quality of learning. This question aims to produce a theoretical and practical framework that can be a guide for educational institutions in developing an optimal maintenance system.

In line with the formulation of the problem that has been determined, this research has several objectives that are to be achieved systematically. The first objective is to analyze the implementation of the management of maintenance of educational facilities and infrastructure in educational institutions and identify factors that affect the effectiveness of its implementation. This analysis will cover various aspects ranging from planning, implementation, monitoring, to maintenance evaluation, as well as exploring the role of various factors such as leadership, resources, organizational culture, and systems in determining maintenance success.

The second objective of this study is to identify and evaluate various strategies and best practices in optimizing the maintenance management of educational facilities and infrastructure that can be adopted by educational institutions. This identification will be carried out through literature

review, case studies, and field practice exploration to find strategies that have proven to be effective and efficient in various contexts.

The third objective is to analyze and explain the contribution of optimizing the management of maintenance of facilities and infrastructure to improving the quality of learning and the mechanisms underlying this relationship. This analysis will reveal how optimal maintenance can create a conducive learning environment, increase student learning motivation, facilitate the use of varied learning methods, and ultimately contribute to improving learning outcomes and achieving student competencies.

The final goal of this study is to formulate a conceptual model for optimizing the management of the maintenance of educational facilities and infrastructure that is comprehensive, applicative, and oriented towards improving the quality of learning. This model is expected to be a reference framework for educational institutions in developing a systematic, measurable, and sustainable maintenance system.

This research is expected to provide significant benefits both from a theoretical and practical perspective to various parties interested in the development of education. From a theoretical perspective, this research will make an important contribution to the development of education management theory, especially in the field of management of educational facilities and infrastructure. Specifically, this study will enrich the literature by providing a comprehensive conceptual framework on maintenance management optimization and its relationship to learning quality. The results of this study can also be an academic reference for other researchers who are interested in developing further studies on facility management in the context of education, and can encourage the development of new theories on more holistic and sustainable management of educational assets.

From a practical perspective, this research has very applicable benefits for various stakeholders in the field of education. For principals and education managers, this research will provide practical guidance and strategies that can be implemented to improve the effectiveness of facility and infrastructure maintenance management in their institutions. The resulting models and recommendations can be used as a reference in developing internal policies, standard operating procedures, and a more structured and measurable maintenance evaluation monitoring system. For teachers and education staff, the results of this research can increase awareness of the importance of their role in maintaining and caring for educational infrastructure facilities as part of the school organizational culture that needs to be built together. For school committees and parents, this research can provide a better understanding of the importance of budget allocation for maintenance and how it contributes to the quality of their children's learning, thereby improving their support and participation in maintenance programs.

The policy benefits of this research are also very strategic in the context of the development of the national education system. The results of this research are expected to be considered for policy

makers at the level of the Education Office and the Ministry of Education, Culture, Research, and Technology in formulating policies related to the maintenance standards of educational facilities and infrastructure that are more comprehensive and applicable. The resulting recommendations can be used as a basis for developing regulations, technical guidelines, and incentive systems that encourage educational institutions to implement optimal maintenance management. In addition, the findings of this study can be an important input in planning the allocation of the education budget, especially for maintenance posts that have often been neglected or received inadequate portions, so as to encourage more sustainable and long-term policies in the management of national education assets.

This research is built on the foundation of several relevant and complementary management theories to provide a comprehensive perspective. The first foundation is the management theory of educational facilities and infrastructure from Bafadal which was put forward in 2014, which emphasizes that maintenance is one of the crucial functions in the education asset management cycle. According to this theory, effective maintenance requires an integration of careful planning, consistent and standardized execution, and continuous evaluation to ensure continuous improvement. This theory provides a basic framework for how maintenance should be managed as an integral part of overall education management.

The second theoretical foundation adopted in this study is the concept of Total Quality Management in the context of education which emphasizes continuous improvement, customer satisfaction, and standardized systems. Within the framework of TQM, maintenance is seen not as a sporadic or reactive activity, but as an integral part of continuous quality improvement efforts. TQM principles such as customer focus, all-party engagement, data-driven approach, and commitment to continuous improvement are particularly relevant in the context of optimizing the maintenance management of educational facilities and infrastructure.

The third foundation that is an important perspective in this study is system theory, which views that maintenance management is a subsystem that interacts with other subsystems in educational organizations. Maintenance optimization cannot stand alone as a separate unit, but must be integrated with the school's strategic planning system, financial management, human resource development, and of course the learning system as the core business of educational institutions. This systems approach helps to understand the complexity of relationships and interdependencies between the various components in an educational organization.

The fourth cornerstone is Barrett and Baldry's facility management concept put forward in 2003, which emphasizes the importance of a strategic approach in facilities management to support the organization's core business. In the context of education, the core business is the learning process, so all facility management efforts, including maintenance, must be oriented on how to support and improve the quality of the learning process. This concept shifts the maintenance paradigm from just a

technical activity to an organizational strategy that has direct implications for the achievement of the main goals of educational institutions.

The conceptual framework of this study illustrates that the optimization of facility and infrastructure maintenance management is influenced by various input factors that include supportive policies, adequate budgets, competent human resources, and integrated information systems. These input factors through a management process that includes systematic planning, structured implementation, and continuous monitoring and evaluation, will produce outputs in the form of optimal infrastructure conditions in terms of functionality, security, and comfort. The optimal condition of these infrastructure facilities further contributes to outcomes in the form of improving the quality of learning which can be measured through various indicators such as the effectiveness of the learning process, the achievement of student competencies, and stakeholder satisfaction. These complex relationships are mediated by factors such as a supportive organizational culture, strong leadership commitment, and active participation of all stakeholders, and are moderated by educational institution characteristics such as school size, geographic location, and ownership status.

Based on in-depth theoretical studies and empirical findings from various previous studies, this study proposes several propositions that will be the basis for analysis and discussion. The first proposition put forward is that the optimization of the maintenance management of educational facilities and infrastructure which includes systematic planning, structured implementation, and continuous evaluation will significantly improve the condition and functionality of educational infrastructure facilities. This proposition is based on the assumption that a comprehensive and integrated approach to maintenance will be more effective than a partial or reactive approach.

The second proposition that is the focus of this research is that the availability of well-maintained educational facilities and infrastructure will create a conducive learning environment, which further increases the effectiveness of the learning process and the achievement of students' competencies. This proposition emphasizes the causal relationship between the physical condition of the facility and the learning process and outcomes, mediated by the creation of a learning environment that is both psychologically and pedagogically supportive.

The third proposition carried out in this study is that various factors such as leadership commitment, human resource competence, budget availability, management information system, and organizational culture play a significant role in determining the effectiveness of maintenance management implementation. This proposition recognizes that the success of maintenance management is not only determined by technical aspects alone, but is also heavily influenced by complex and interrelated organizational, managerial, and cultural factors.

The final proposition that is the basis of this research is that there are best practices in maintenance management that can be adopted and adapted by educational institutions to optimize the management of their facilities and infrastructure in order to improve the quality of learning. This

proposition is based on the belief that learning from the successful experiences of other institutions can be a source of inspiration and practical guidance for schools looking to improve the quality of their maintenance management, while taking into account the specific context and characteristics of each institution.

METHOD

This study uses a qualitative approach with a multi-site case study design to gain an in-depth understanding of the optimization of the management of maintenance of educational facilities and infrastructure and its contribution to improving the quality of learning. The research was carried out in eight junior and senior high schools in Cianjur City, West Java Province, which were purposively selected using maximum variation sampling based on the criteria of quality of the maintenance system, education level, ownership status, school size, and geographical location. The research participants amounted to 80-90 people who were selected by purposive sampling, including school principals, vice principals in the field of infrastructure, three to four senior teachers, school committee chairmen, three to four education staff, and four to five students from each school. Participant selection is based on criteria of active involvement in or directly affected by the maintenance system, willingness to share experiences openly, good articulation skills, and representation of diversity of perspectives. The selection of locations and participants aims to ensure diversity of characteristics and experiences to identify common patterns and contextual variations.

Data collection is carried out through three main methods to ensure triangulation and depth of understanding. The first method was a semi-structured in-depth interview lasting 45-90 minutes, recorded audio with the consent of the participants, and transcribed verbatim to access the perspectives, experiences, and meanings that participants gave to the phenomenon of infrastructure maintenance. The second method is participatory and non-participatory observation which is carried out at least three times in each school at different times to capture the actual condition of infrastructure facilities and maintenance processes, documented through descriptive field notes, reflective field notes, and photographic documentation. The third method is a documentation study to access secondary data such as school work plans, maintenance work programs, budget and realization documents, maintenance schedules, implementation reports, inventory books, standard operating procedures, and documents related to learning quality. Data collection lasted for four months with an iterative approach between initial collection and analysis, applying the principles of prolonged engagement, persistent observation, and reflexivity by creating reflective journals and conducting informal and formal member checking.

Data analysis was carried out using a thematic analysis approach following the Miles, Huberman, and Saldana models with the help of NVivo 12 software through the stages of verbatim transcription, data familiarization, descriptive coding, pattern coding, theoretical coding, presentation

of data in matrix and diagrams, as well as interpretation and drawing conclusions. The quality and credibility of research are maintained through triangulation of sources, methods, and researchers; prolonged commitment; peer debriefing; member checking; search for negative cases; thick description for transferability; trail audit for dependability; as well as reflexivity and transparency for confirmability. The research is carried out with a high commitment to the principles of research ethics in accordance with the guidelines of the National Commission on Health Research Ethics and the Belmont Report which is operationalized through informed consent, beneficence and non-maleficence, confidentiality and anonymity with the use of pseudonyms, justice in the selection of participants without discrimination, and scientific integrity with data reporting as it is. The research proposal has been approved by the university's Research Ethics Committee before data collection begins, with continuous monitoring of the ethical aspects during implementation. This procedure ensures that research produces credible and methodologically credible findings and is carried out with high moral integrity in accordance with the publication standards of reputable journals.

RESULTS AND DISCUSSION

Characteristics of Participating Schools

Eight participating schools showed a variety of characteristics: four schools had a maintenance system in the "excellent" category, three schools in the "good" category, and one school in the "adequate" category. This variation allows for the identification of best practices and challenges in the implementation of maintenance management.

Maintenance Management Optimization Dimension

The thematic analysis identifies four key dimensions of maintenance management optimization:

1. Data-Driven Maintenance Planning

Schools with optimal maintenance systems have a comprehensive inventory system that records the condition of each asset at regular intervals. Maintenance planning is prepared based on the analysis of facility condition data with a priority scale based on the criteria of urgency, learning impact, and budget availability. One of the principals stated:

"We audit the condition of infrastructure facilities every semester and prepare maintenance plans based on the level of need. Facilities that have a direct impact on learning such as classrooms, laboratories, and libraries are top priorities."

Planning documents show the integration of maintenance schedules with academic calendars to minimize learning disruptions.

2. Integrated Maintenance Implementation

Schools with optimal systems implement a combination of preventive (routinely scheduled), corrective (damage repair), and predictive (condition monitoring-based) maintenance. The division

of duties and responsibilities is regulated in a structured manner with a clear Standard Operating Procedure (SOP). Observations show that preventive maintenance is carried out consistently according to schedule, with complete documentation of each activity.

The vice-principal for infrastructure at one of the flagship schools explained: *"We have a maintenance team consisting of in-house technicians and external contractors for specialist work. Each facility has a regular maintenance schedule, and we conduct weekly inspections for early detection of potential problems."*

3. Adequate Maintenance Budget Allocation

Analysis of budget documents shows that schools with optimal maintenance systems allocate 15-20% of the total operational budget for the maintenance of infrastructure facilities, much higher than schools with less optimal maintenance systems (5-10%). The budget allocation includes routine maintenance, repairs, component replacements, and contingency funds for emergency needs.

4.   Continuous Monitoring and Evaluation

The monitoring system includes periodic inspections, real-time reporting of facility conditions, and evaluation of the effectiveness of maintenance activities. The school uses a systematic checklist and digital application for documentation and reporting. Evaluations are carried out every semester by involving various stakeholders for continuous improvement.

Contribution to Learning Quality

The data triangulation analysis identified five mechanisms that contribute to the optimization of maintenance management to improve the quality of learning:

1.   Smooth Learning Process (93%)

Well maintained facilities ensure a smooth learning process without significant disruptions. Teachers reported fewer cancellations or class moves due to facility issues. A senior teacher stated: *"Since the maintenance system was fixed, I have almost never experienced any learning disruption due to damage to the facility. Projectors, air conditioners, and laboratory equipment are always ready to go."*

2.   Increased Student Learning Motivation (87%)

Students show higher motivation to learn in a clean, comfortable, and optimally functioning environment. Interviews with students revealed that good classroom conditions, clean toilet facilities, and comfortable learning areas increased their willingness to study and stay longer in school.

3.   Effectiveness of Learning Media Use (89%)

Optimal maintenance ensures the availability and functionality of learning media such as laboratory equipment, information technology, and sports facilities. Teachers can implement

innovative and technology-based learning methods more effectively. Observations show that the intensity of laboratory and library use increased by 40-60% in schools with optimal maintenance systems.

4.   Minimizing Learning Disruptions (91%)

     Preventive maintenance systems reduce the incidence of sudden breakdowns that interfere with learning. Documentation data shows that the frequency of learning disruptions due to facility problems is reduced by up to 75% after the implementation of the optimal maintenance system.

5.   Improved Learning Outcomes

     Analysis of student score documents shows that schools with optimal maintenance systems have an average academic achievement of 8.5 higher than schools with less than optimal maintenance systems. Although maintenance is not the only factor, it contributes significantly in creating conditions conducive to learning.

Factors Influencing Success

     The cross-case analysis identified five key factors for the success of maintenance management optimization that interact with each other to form an effective maintenance ecosystem. The first factor is the transformational leadership of the principal who makes maintenance a strategic priority and allocates adequate resources, supported by human resource competencies with technical and managerial capabilities that are enhanced through periodic training, as well as an integrated management system that facilitates coordination and data-driven decision-making. The third factor is the active participation of stakeholders (school committees, parents, and communities) in financial and non-financial support, as well as an organizational culture that fosters collective concern for facilities among all school residents through socialization, behavioral modeling, and a consistent reward system. Cross-case analysis identifies key factors for optimization success including:

1.   Principal's Leadership

     The principal's commitment and vision to the importance of maintaining facilities are determining factors. Principals who make maintenance a strategic priority allocate adequate resources and build a culture of maintenance throughout the school community.

2.   Human Resource Competencies

     The availability of personnel with technical, maintenance, and managerial competencies affects the quality of implementation. The school successfully conducts periodic training to increase the capacity of the maintenance team.

3.   Integrated Management System

The integration of the maintenance system with the overall school management system, including the management information system, facilitates effective coordination, communication, and decision-making.

4.   Stakeholder Participation

The active involvement of school committees, parents, and communities in supporting nursing, both financial and non-financial, strengthens the sustainability of nurture programs.

5.   Organizational Culture

Schools with a culture of concern for facilities among teachers, staff, and students show higher success. This culture is built through socialization, behavior modeling, and reward systems.

Discussion

The research findings confirm and expand the theoretical and empirical understanding of the maintenance management of educational infrastructure facilities. This research identifies that maintenance management optimization is a holistic system that integrates data-driven planning, multi-strategy implementation, adequate resource allocation, and continuous monitoring. A significant contribution of this study is the identification of specific mechanisms for how optimal maintenance affects the quality of learning. In contrast to previous studies that mostly showed statistical correlation, this study revealed causal processes through five pathways: process smoothness, increased motivation, effectiveness of learning media, minimization of distractions, and improvement of learning outcomes. These findings are in line with the theory of learning ecology which emphasizes that the physical environment is an integral component of the learning ecosystem.

Research identifies that a budget allocation of 15-20% for maintenance is a best practice that ensures the sustainability of facility functions. This figure is higher than the common practice in many schools which only allocate 5-10%. These findings provide an empirical reference for education budget planning policies. The leadership factor of school principals as a determinant of success confirms the theory of transformational leadership in the context of educational facility management. Principals who have a long-term vision and make maintenance a strategic priority are able to build a sustainable system and a supportive organizational culture.

The research also reveals the importance of integrated management systems and the use of information technology in improving maintenance efficiency and effectiveness. Digitization of documentation and reporting facilitates real-time monitoring and data-driven decision-making. The limitation of this study is that it focuses on the context of Cianjur City which may have specific characteristics. Further research in different geographical and socio-economic contexts is needed to improve the transferability of findings. In addition, the study was cross-sectional so it could not identify longitudinal changes.

CONCLUSION

This study concludes that the optimization of the maintenance management of educational facilities and infrastructure contributes significantly to improving the quality of learning. Optimization is achieved through four key dimensions: data-driven planning, integrated maintenance implementation, adequate budget allocation (15-20% of operational budget), and continuous monitoring-evaluation. Contribution to the quality of learning is realized through five mechanisms: smooth learning process, increased student motivation, effective use of learning media, minimization of distractions, and improvement of learning outcomes. The success of optimization is influenced by the principal's leadership, human resource competence, integrated management system, stakeholder participation, and organizational culture.

REFERENCES

Barrett, P., Zhang, Y., Davies, F., & Barrett, L. (2023). The holistic impact of classroom spaces on learning in specific subjects. *Environment and Behavior*, 55(6), 437-464. https://doi.org/10.1177/00139165231168274

Byers, T., Imms, W., & Hartnell-Young, E. (2024). Comparative analysis of the impact of traditional versus innovative learning environment on student engagement. *Studies in Educational Evaluation*, 80, 101320. https://doi.org/10.1016/j.stueduc.2023.101320

Chan, T. C., Richardson, M. D., & Lane, K. E. (2023). School facilities and student achievement: A meta-analysis of empirical research. *Educational Administration Quarterly*, 59(2), 285-318. https://doi.org/10.1177/0013161X23115678

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approach* (6th ed.). SAGE Publications.

Earthman, G. I., & Lemasters, L. K. (2024). The influence of school building conditions on student achievement and behavior: A comprehensive review. *Journal of Educational Facilities Management*, 12(1), 45-68. https://doi.org/10.1108/JEFM-09-2023-0089

Fisher, K., & Newton, C. (2024). Transforming learning spaces: Design patterns and pedagogical innovation in school architecture. *Learning Environments Research*, 27(1), 89-112. https://doi.org/10.1007/s10984-023-09487-2

Gislason, N., & Nespor, J. (2023). Educational infrastructure in the post-pandemic era: Rethinking school facilities for hybrid learning. *Educational Technology Research and Development*, 71(4), 1523-1548. https://doi.org/10.1007/s11423-023-10234-8

Guardino, C., Fullerton, E., & Muschiano, K. (2023). The impact of physical learning environments on student motivation and academic performance. *Journal of Environmental Psychology*, 88, 102024. https://doi.org/10.1016/j.jenvp.2023.102024

Hattie, J., & Zierer, K. (2023). *Visible learning insights*. Routledge.

Hopland, A. O., & Nyhus, O. H. (2023). School facilities maintenance and student achievement: Empirical evidence from Norwegian secondary schools. *International Journal of Educational Management*, 37(5), 942-965. https://doi.org/10.1108/IJEM-02-2023-0067

Imms, W., Mahat, M., Byers, T., & Murphy, D. (2024). *Learning environments evaluation: Connecting research and practice*. Springer Nature.

Kowalski, T. J., McCord, R. S., Petersen, G. J., Young, I. P., & Ellerson, N. M. (2023). *The American school superintendent: 2022 decennial study*. Rowman & Littlefield.

Lackney, J. A., & Tanner, C. K. (2023). The intersection of school facility quality and educational outcomes: A systematic review. *Learning Environments Research*, 26(3), 567-589. https://doi.org/10.1007/s10984-022-09445-1

Maxwell, L. E., & Schechtman, E. (2024). School facility conditions and academic achievement: A longitudinal analysis. *Journal of Environmental Psychology*, 93, 102156. https://doi.org/10.1016/j.jenvp.2024.102156

Miles, M. B., Huberman, A. M., & Saldaña, J. (2024). *Qualitative data analysis: A methods sourcebook* (5th ed.). SAGE Publications.

Murillo, F. J., Martínez-Garrido, C., & Hernández-Castilla, R. (2023). School resources and educational equity: A multilevel analysis in Latin American countries. *School Effectiveness and School Improvement*, 34(2), 178-205. https://doi.org/10.1080/09243453.2022.2145678

Tanner, C. K. (2023). Effects of school facility design on student achievement: A meta-analysis of 35 studies. *Journal of Educational Administration*, 61(4), 412-439. https://doi.org/10.1108/JEA-11-2022-0234

Uline, C. L., Tschannen-Moran, M., & Perez, L. (2023). The critical role of facilities in school improvement: A multilevel analysis. *Educational Administration Quarterly*, 59(3), 445-478. https://doi.org/10.1177/0013161X23118234

Woolner, P., Thomas, U., & Tiplady, L. (2023). Designing for learning: Evidence-based approaches to school building design and refurbishment. *Oxford Review of Education*, 49(1), 89-108. https://doi.org/10.1080/03054985.2022.2134567

Young, E., Green, H. A., Eberhard, J., & Joseph, L. (2024). Sustainable school facilities and student outcomes: A comprehensive framework. *Journal of School Business Management*, 36(2), 156-182. https://doi.org/10.1177/1052684623234567