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REVISTA INGENIO

Assessment of Bim-Facility Management for the Potentialization of Sports Infrastructure. Case Study.

Valoración de Bim-Facility Management para la Potencialización de Infraestructura Deportiva. Caso de Estudio.

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PALABRAS CLAVE
BIM-FM, Infraestructura deportiva, Sostenibilidad, Mantenimiento preventivo.

RESUMEN
Este estudio evalúa la aplicación de la metodología BIM-FM como herramienta para la gestión, análisis y optimización de infraestructura deportiva existente. Se seleccionó como caso de estudio la Piscina Olímpica El Batán, ubicada en Quito – Ecuador, que presenta más de 40 años de antigüedad y carece de documentación técnica actualizada. A través de un levantamiento in situ, se generó un modelo BIM que permitió realizar simulaciones de iluminación y ventilación natural. Los resultados evidenciaron deficiencias operativas, pero también la viabilidad de mejorar su rendimiento sin necesidad de demoler. La implementación de paneles LED y claraboyas ventiladas incrementó la eficiencia energética y el confort térmico. Se concluye que BIM-FM representa una herramienta estratégica para extender la vida útil de infraestructuras deportivas, mejorar su sostenibilidad operativa y facilitar la planificación de mantenimiento preventivo, incluso en contextos con limitaciones tecnológicas. Este enfoque aporta a la gestión responsable del entorno construido con impacto ambiental y económico reducido.

KEY WORDS
BIM-FM, Sports infrastructure, Sustainability, Preventive maintenance.

ABSTRACT
This study assesses the application of the BIM-FM methodology as a tool for managing, analyzing, and optimizing existing sports infrastructure. The Olympic Pool "El Batán" in Quito, Ecuador, was selected as a case study due to its age—over 40 years—and lack of updated technical documentation. A BIM model was developed through on-site data collection, enabling lighting and natural ventilation simulations. The results revealed operational inefficiencies but also the feasibility of improving performance without requiring demolition. Implementing LED panels and ventilated skylights improved energy efficiency and thermal comfort. It is concluded that BIM-FM is a strategic tool for extending the lifespan of sports infrastructure, enhancing operational sustainability, and facilitating preventive maintenance planning, even in contexts with technological limitations. This approach contributes to responsible built environment management with reduced environmental and economic impact.

1. INTRODUCTION

The construction sector is one of the highest producers of waste and innovators of resources in Europe [1]. The environmental and economic impact generated by construction and demolition waste makes it one of the greatest challenges in the AEC industry [2]. In addition, the most significant proportion of a building's energy consumption occurs during the operation and maintenance (O&M) stage, which, although not the final stage, is the longest within the building's life cycle [3]. In light of this, sustainable building renovation is an alternative for addressing environmental problems and the energy crisis, especially given that the construction sector accounts for more than 40% of global energy consumption [4].

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It is estimated that two-thirds of current buildings will remain in use in 2050, and more than 40% were built before 1960, when energy efficiency regulations were still in their infancy [5]. However, only between 0.5% and 1% of the global inventory is renovated annually, highlighting the urgent need to accelerate renovation processes [6]. Faced with this challenge, the AEC industry has focused its efforts on innovative construction methodologies and the use of sustainable materials, with advances such as the development of permeable paving stones, the incorporation of nanographene in mortars, and the exploration of silica nanoparticles as an alternative to Aerosil 200 [7], [8], [9]. However, there is still limited attention to comprehensive management models that enable feasible projects and ensure an effective and sustainable reduction of the environmental impact in the sector.

Most studies on Building Information Modeling (BIM) focus on the development of new projects from their planning or construction phase, neglecting its application to existing operational infrastructure [10]. Nevertheless, it is presented as a continuously developing methodology that offers several benefits during the operation and maintenance phase, such as better facility management, efficient energy use, cost-effective modernization decision-making, planned repair work, and organized demolition, among others [11]. In addition, BIM not only provides convenience for subsequent property management, but also provides effective historical information for possible renovation and expansion interventions, the development of automated processes, real-time data review, and the application of the Lean Construction philosophy [12], [13].

According to different data sources, current methods for digitizing BIM models of existing infrastructure can be divided into two categories: methods based on in situ data and methods based on external data [3]. Current techniques based on on-site data are mainly digital photogrammetry, terrestrial laser scanning, and ground-penetrating radar. These techniques involve laborious studies with manual measurement or visual assessment, are prone to errors, are time-consuming, are often unreliable, and create significant uncertainty for decision-makers [11]. On the other hand, current techniques based on external data mainly use existing construction documents, especially 2D construction drawings. A significant advantage of this type of approach is that 2D drawings contain a wealth of project information, which facilitates the creation of information-rich 3D models [3].

As a system, the BIM model of the building must reflect the actual state of the equipment, facilities, materials, and finishes, among other useful information related to operation and maintenance [13]. BIM is still immature for full adoption in remodeling projects due to technical, informational, and organizational complications [14]. The main challenges hindering progress in the implementation of BIM in existing buildings are: (1) high effort of modeling/converting captured construction data into BIM semantic objects; (2) updating information in BIM; and (3) handling uncertain data, objects, and relationships in BIM that occur in existing buildings [15], [16].

The implementation of BIM in both new and existing buildings induces profound changes in processes and information flows, but it also generates considerable advantages; the calculation of alternatives and optimizations seems promising for improving project management and risk mitigation or limiting the costs and duration of Facility Management (FM) measures[16], [17].

According to ISO 41011:2017, FM is the "organizational function that integrates people, places, and processes within the built environment for the purpose of enhancing the quality of life of people and the productivity of the core business," while the IFMA (International Facility Management Association) defines it as "the process of design, implementation, and control by which facilities are identified, specified, found, and supplied in order to provide and maintain those levels of service capable of meeting business needs, creating a quality work environment at the lowest possible cost" [18]. FM accounts for 80% of total costs during the life cycle of a building, mainly due to reactive maintenance; BIM can reduce the amount of reactive maintenance performed during operation through preventive maintenance scheduling and conflict prediction [19].

The digitization of infrastructure buildings seems to have become increasingly essential for their care and reuse; for this reason, it is necessary to increase knowledge about building assets to support sustainable maintenance and conservation strategies through the development of easy-to-use resource management tools [18].

FM can be an alternative to reduce waste generation and prolong the effectiveness of O&M processes [20]. During this phase, BIM methodology can be useful in areas such as space management, fit-out control, facility monitoring, maintenance, and repairs [21], as well as being a useful tool for the sustainable analysis of buildings, from energy consumption quantification to waste management and from the planning, administration, coordination, and evaluation of the daily operations of an infrastructure [22], [23].

There are several challenges to implementing BIM in FM, notably the lack of data or obsolete information, technical, cost, organizational, and legal challenges [5]. Previous studies have demonstrated the potential of BIM in the revitalization of heritage buildings (HBR), although it has not yet been developed to an optimal level to achieve this [24]. Open BIM approach is effective in terms of data quality, while FM allows for a balanced approach to the adaptation of heritage buildings, a solid user experience, and broader community effects, enabling efficient decision-making, creative facility design, and effective public participation [25], [26]. On the other hand, BIM has the potential to facilitate strategic decision-making by integrating a wide range of information related to the physical condition of built assets and available resources [27], [28].

Currently, much of the information required for FM is still stored in two-dimensional physical documentation and delivered to the owner months after the facilities become operational [29]. The FM team requires access to building components to perform inspection and maintenance work in real time and remotely [30]. In response to this, studies provide a template of information required by FM professionals, detailing the main information necessary for its implementation in BIM projects [31].

Within this context, sports buildings are of great interest because they are not always built from scratch and, in some cases, involve pre-existing objects [32], [33]. The methodological recycling of structures requires careful evaluation in order to make efficient decisions that do not jeopardize the project and guarantee the expected results [34].

The use of BIM-FM in sports infrastructure management offers economic, environmental, and administrative benefits that strengthen the sustainability and efficiency of these projects. Economically, its implementation allows for precise resource management, reducing operating, maintenance, and repair costs, as well as optimizing the use of materials and extending the useful life of facilities. From an environmental perspective, BIM-FM facilitates ecological impact assessment, improves energy efficiency, reduces debris generation, and promotes the responsible use of materials, ensuring that facilities are sustainable in the long term.

At the administrative level, this digital methodology improves coordination between actors, supports informed decision-making, and enables long-range planning with high-quality results. The digitization of existing sports infrastructure opens up the possibility of implementing new management models under FM criteria, which promotes efficient maintenance, extends the useful life of facilities, and avoids unnecessary demolitions that generate waste.

The main objective of this study is to evaluate the applicability and measurable benefits of integrating BIM-FM into sports infrastructure management by quantifying improvements in operational performance, lighting efficiency, ventilation, and maintenance planning. The hypothesis is that its implementation can increase these indicators by more than 20% compared to the baseline. In this way, BIM-FM is presented as an environmentally responsible and economically viable alternative, aligned with innovation and sustainability in the construction sector.

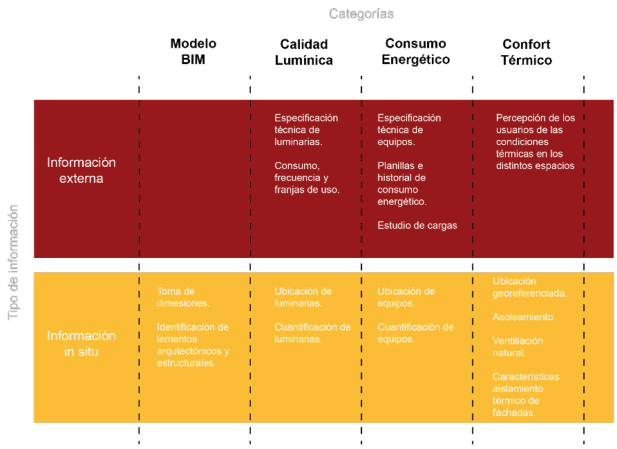
2. METHODOLOGY

The scope of this research covered only sports infrastructure that meets the following characteristics: i) current structural design life of no less than 20 years, ii) no BIM model available, iii) managed under conventional methodologies or without management, and iv) evidence of significant physical wear and tear in general.

This study was limited to assessing the benefits achieved in terms of energy consumption, lighting quality, thermal comfort, and the new advantages generated in the operation and maintenance phase. Fig. 1 details the information considered, classified according to its source.

Fig. 1.

Type and source of information collected.

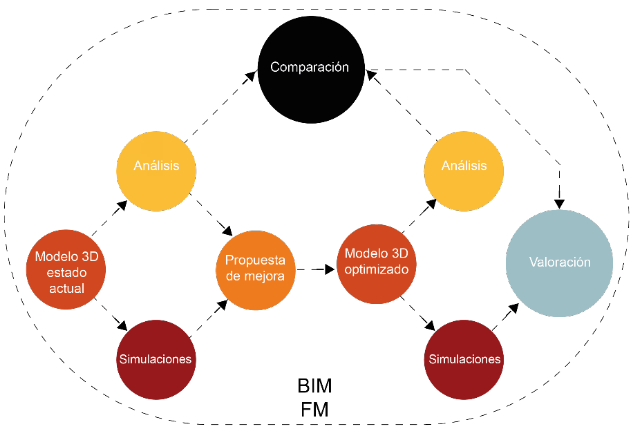


The BIM model was developed in Autodesk Revit 2023, integrating architectural, structural, and MEP layers based on a survey using manual measurements on site. Lighting simulations were performed in DIALux evo 10.1, applying the parameters established in the EN 12193 standard for sports lighting, with a calculation grid of 0.5 m and a working plane at a height of 0.85 m. The ventilation analysis was performed in Autodesk CFD 2022, using a tetrahedral mesh with an average element size of 0.25 m and boundary conditions defined according to ASHRAE 62.1. With the results obtained, the critical aspects to be addressed were determined and alternatives for improvement were proposed, which were developed in an optimized model to be analyzed again and implemented in BIM-FM in the aforementioned software. Finally, the benefits were assessed by comparing the results obtained initially with the information extracted from the enhanced model, and the investment that would be involved in implementing the identified improvement alternatives was quantified, as well as their return time.

The current environment, marked by constant transformation and instability, drives organizations to differentiate themselves by generating greater value for their customers [35]. In this context, entities that own or manage sports infrastructure must ensure that facilities are up to date and in line with the changing demands of users and visitors. The Pichincha Sports Association, one of Ecuador's most important sports organizations with more than 100 years of history, was founded with the aim of promoting sports in the province and integrating its different communities. In order for the results of the study to be replicated in other infrastructures of this entity, the

Fig. 2.

Flowchart of the methodology applied.



El Batán Olympic Swimming Pool in Quito was selected as a case study because it meets the necessary characteristics for this purpose.

Fig. 3.

Photography of El Batán Olympic Swimming Pool.

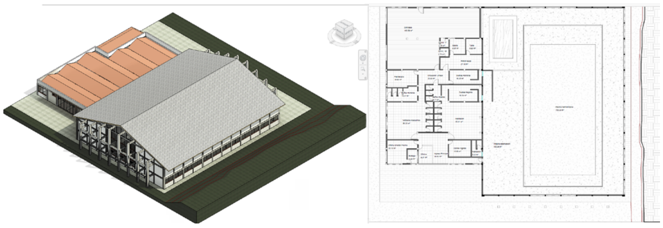
3. RESULTS AND DISCUSSION

The main objective of this study was to evaluate the applicability of the BIM-FM methodology in an existing sports facility, with the purpose of generating a digital model capable of supporting informed decisions in the management, operation, and maintenance phases. The following sections present the principal results obtained and a technical discussion of their implications for facility performance and sustainability.

One of the initial challenges identified was the inability to employ advanced surveying technologies such as terrestrial laser scanning (TLS), aerial photogrammetry, or ground-penetrating radar (GPR), due to their limited availability and high implementation costs in Ecuador. These constraints led to the adoption of a manual in-situ survey, based on direct dimension measurement and photographic documentation of the architectural and structural components.

Fig. 4.

BIM model and main floor plan of current state.



While this approach enabled the development of a functional BIM model, the level of detail achieved was constrained by the lack of access to embedded infrastructure data—such as plumbing routes, electrical conduits, and HVAC systems—which are typically critical for facility management. The absence of historical construction records further reduced modeling precision, introducing an inherent level of uncertainty that is characteristic of BIM applications in pre-existing structures [16], [17].

Despite these limitations, the model provided sufficient geometric and semantic accuracy to perform technical simulations and serve as a base for operational analysis, supporting the premise that even manually built BIM datasets can yield valuable insights when appropriately calibrated.

The visual inspection confirmed that the main metallic structure, despite its four decades of use, remains in good physical and mechanical condition, with no signs of corrosion or deformation compromising stability. This finding indicates that non-structural refurbishment strategies are both feasible and economically rational for extending the facility's lifecycle. Operationally, the building lacks a formal maintenance system, relying on reactive interventions triggered by visible deterioration or functional failure. The only available operational data consisted of electricity bills from the previous six months and spot thermal measurements taken during different times of the day for a one-month period. These observations confirm that sports infrastructures in Ecuador generally operate with limited asset management frameworks, which results in resource inefficiency and higher long-term costs.

The introduction of BIM-FM as a digital management framework thus represents an opportunity to transition from reactive to preventive maintenance, enabling the creation of a dynamic database that progressively enriches itself through real-time monitoring and documentation of interventions.

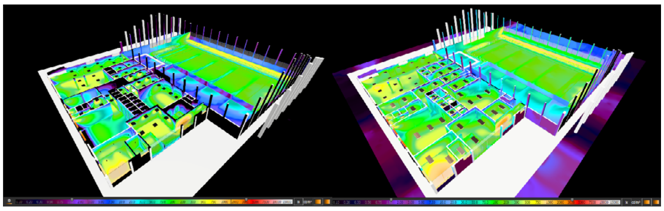
Lighting simulation conducted in DIALux Evo 13.1 revealed significant deficiencies in the existing system. The current configuration provided an average illuminance of

180 lux, with a minimum of 95 lux in secondary corridors and 215 lux over the main pool deck. These values fall below the EN 12193:2019 standard, which recommends a minimum of 250 lux for competitive swimming environments. The non-uniform light distribution resulted in a uniformity ratio (U_0) of 0.46, indicative of uneven lighting conditions and potential visual discomfort for users.

In the proposed improvement scenario, LED panel lighting (30 W, 110 lm/W) was integrated along with ventilated skylights designed to enhance both daylight penetration and passive ventilation. Simulation results demonstrated an average illuminance of 290 lux, achieving compliance with the European standard and representing a 61% improvement. Additionally, the system showed an estimated 28% reduction in energy consumption due to the higher efficiency of LED fixtures and reduced artificial lighting demand during daytime hours. The uniformity ratio improved to 0.72, indicating a more evenly distributed lighting field, beneficial for both user comfort and safety.

Fig. 5.

Current status (a) and proposed improvement (b) of lighting quality.



(a) (b)

Computational Fluid Dynamics (CFD) simulations performed using Autodesk CFD 2024 revealed critical thermal zones in the pool area, characterized by air stagnation and elevated operative temperatures averaging 33°C, with localized pockets exceeding 35°C near the roof structure. These conditions stem from the absence of cross-ventilation openings and the poor thermal conductivity of the existing metallic roof. The low air velocity—below 0.2 m/s—contributed to heat accumulation and user discomfort, as well as increased evaporation rates from the pool surface.

In the improved scenario, the integration of ventilated skylights and roof panels with thermal insulation (λ = 0.035 W/m·K) substantially altered internal airflow dynamics. Average air velocity increased by 35%, reaching values between 0.25–0.35 m/s, while the operative temperature decreased to 29°C, aligning with the comfort thresholds established by ASHRAE 55 and ASHRAE 62.1. The improved airflow distribution minimized stagnant zones and created a more uniform thermal gradient, suggesting that low-cost architectural interventions can significantly enhance indoor air quality in existing sports facilities without the need for mechanical systems.

The comparative analysis between the current and improved scenarios (Table 1) confirms that targeted retrofitting interventions, informed by BIM-FM simulations, can produce substantial functional and environmental gains with relatively minor physical alterations. The lighting system achieved standard compliance, energy efficiency increased notably, and thermal comfort improved measurably, all without structural modifications.

From a management perspective, the BIM-FM framework proved effective for integrating multi-domain data (lighting, ventilation, energy) into a unified model, allowing decision-makers to visualize operational inefficiencies and quantify the potential return on investment for each improvement. This capability aligns with international research that positions BIM-FM as a strategic enabler for sustainable facility management [18], [21].

Furthermore, the findings demonstrate that in regions with technological and economic limitations, low-tech BIM applications remain a feasible path toward digital transformation in infrastructure management. The adoption of standardized data formats (IFC) ensures scalability, while progressive data enrichment can evolve into predictive maintenance models integrating IoT sensors and performance dashboards.

The outcomes of this case study demonstrate that medium-scale sports infrastructures can effectively extend their functional lifespan through data-driven, non-structural retrofits. This approach aligns with the principles of circular economy and sustainable development by minimizing demolition waste, optimizing energy performance, and reducing the environmental footprint of the built environment.

The methodological contribution of this research lies in demonstrating the feasibility of implementing BIM-FM in resource-constrained contexts, offering a replicable framework adaptable to other public or institutional facilities in Latin America. The progressive integration of facility data through BIM-FM will enable more accurate long-term planning, cost forecasting, and operational resilience, thereby transforming traditional building maintenance into a proactive, knowledge-based discipline.

4. CONCLUSIONS

This research confirms that the implementation of the BIM-FM methodology in existing sports facilities constitutes a technically feasible and methodologically robust strategy for optimizing management, maintenance, and operation processes throughout the building lifecycle. The case study developed on a semi-Olympic swimming pool over 40 years old demonstrated that, even in the absence of detailed historical documentation, it is possible to generate a functional and informative digital model that serves as a foundation for decision-making and sustainability planning.

TABLE I.
Comparative analysis of current state and proposed improvement.

Parameter	Current State	Improved Scenario	Variation	Standard Reference
Average illuminance (lux)	180	290	+61%	EN 12193 ≥ 250 lux
Uniformity ratio (U_0)	0.46	0.72	+57%	EN 12464-1 ≥ 0.6
Estimated energy consumption (kWh/month)	2,140	1,540	−28%	—
Air velocity in pool deck (m/s)	0.18	0.27	+35%	ASHRAE 62.1: 0.25–0.35
Average temperature (°C)	33	29	−12%	ASHRAE 55: 28–30
Estimated CO_2 emissions (kg/year)*	4,200	3,000	−29%	—

The quantitative outcomes derived from the model simulations validate the effectiveness of BIM-based analyses. Lighting optimization through the integration of LED technology and ventilated skylights produced an average 61% improvement in illuminance, increased uniformity from 0.46 to 0.72, and achieved an estimated 28% reduction in energy consumption. Similarly, the application of passive ventilation strategies yielded a 35% increase in air velocity, reducing stagnant zones below 0.2 m/s, and a 4°C decrease in average indoor temperature, aligning with ASHRAE comfort standards. These results confirm that targeted, non-structural interventions can substantially improve the environmental and operational performance of aging facilities without requiring large-scale reconstruction.

From an operational management perspective, the incorporation of BIM-FM marks a transition from a reactive maintenance approach—based on corrective interventions—to a preventive and predictive model, where technical data are continuously recorded, updated, and analyzed. This paradigm shift enables the establishment of data-driven maintenance plans, real-time monitoring dashboards, and historical records that enhance transparency, efficiency, and traceability in facility management processes. The digital twin thus becomes a strategic asset that evolves with each operational cycle, improving long-term planning and resource allocation.

Moreover, the study highlights that even under technological and economic limitations, low-tech BIM implementations can produce high-impact outcomes. The methodology demonstrated its adaptability to contexts with scarce documentation, confirming that its success depends more on structured processes and data interoperability than on advanced hardware availability. In this regard, the use of open formats such as IFC ensures scalability, while the progressive enrichment of the model supports continuous improvement in facility operations.

In broader terms, this research contributes to the ongoing discussion on the sustainable management of existing infrastructure, particularly in the Global South. The BIM-FM framework provides a tangible path toward reducing environmental impact by extending the useful life of buildings, minimizing construction waste, and lowering energy demand. Its adoption aligns with global sustainability objectives and supports the circular economy principles advocated by contemporary building management standards.

Finally, the results suggest several lines for future research and application. First, integrating IoT and sensor-based monitoring systems with the BIM-FM environment could enhance real-time data acquisition and predictive maintenance capabilities. Second, expanding this methodology to other types of public and educational facilities would validate its scalability and adaptability. Third, the combination of BIM-FM with cost-benefit and lifecycle analysis tools would provide decision-makers with a more comprehensive understanding of the economic and environmental returns of renovation projects.

In conclusion, the implementation of BIM-FM in existing sports infrastructures represents not only a tool for improving operational performance but also a transformative management approach that fosters informed decision-making, sustainability, and resilience. As digital technologies evolve and become more accessible, their integration into the Facility Management domain will play a decisive role in the responsible modernization of the built environment across developing regions.

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