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The evolution of BIM work standards: current, best, and future practices from a BIM Manager's perspective

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Abstract:
This study analyzes the evolution of working standards in Building Information Modeling (BIM) and the redefinition of the role of the BIM Manager in the era of digital transformation. The starting point is the identification of a cognitive gap, i.e., the discrepancy between the exponential growth of data and the limitations of human perception. The conclusions are based on a narrative review of over 100 publications, with artificial intelligence models used in the content synthesis process. The analysis proves that implementing AI requires prior digital hygiene in accordance with the ISO 19650 standard and the conversion of data into a machine-readable format. Attention was also drawn to the phenomenon of the productivity paradox, showing that the automation of erroneous or inefficient processes only leads to the faster generation of defects. The paper outlines a vision of the future in which OpenBIM standards become the language of algorithm communication and AR technology ensures continuity of quality control. At the same time, the analysis emphasizes that the success of the transformation does not depend solely on technology, but on the soft and leadership skills necessary to overcome process resistance. The whole is crowned with a forecast of the evolution of the BIM Manager into a Knowledge Architect and transformation leader who oversees autonomous processes in a *human-in-the-loop* model.

Keywords:
BIM, BIM manager, AI, Digital Twin, generative design, OpenBIM, human-in-the-loop

1. Introduction

There is no single, universally accepted definition *of Building Information Modeling* (BIM) in scientific literature, and the interpretation of this term evolves with technological progress [1]. The ISO 19650-1:2018 standard defines the concept as "the organization and digitization of information about construction and engineering objects," pointing to its systemic nature that goes beyond the technological aspect [2]. This perspective is often extended to include a dualistic approach, treating BIM as both an information system and a philosophy of industry transformation [3]. At the same time, the literature points to a strong correlation between this concept and *digital twins*, emphasizing the importance of real-time data integration [4,5]. The central elements of this environment are the BIM model, which is a three-dimensional digital representation of an object developed throughout its entire life cycle [6], and the BIM Manager who manages it. This role has undergone a fundamental redefinition, evolving from that of a technical supervisor of the model and a person responsible for standardizing tools to that of a strategist [1,7,8]. The literature on the subject emphasizes that the modern BIM Manager is no longer limited to the role of tool administrator but is a manager responsible for the organization's digital assets [9,10]. The scope of responsibilities in this position, although correlated with the scale of the project [7,11,12], is shifting more and more clearly towards management [8]. It now includes the integration of BIM processes with the company's business strategy [8], risk management and *dispute avoidance* [13], and ensuring data interoperability for *Facility Management* through openBIM standards [14,15]. This requires placing the BIM Manager in the decision-making hierarchy between the investor's requirements and the project management level [3,16]. In light of the first part of the ISO 19650 standard, there is a shift away from statically defined positions towards flexible information management functions [12,17], which positions the manager as a leader in the socio-technical system [3]. The implementation of BIM constitutes a profound transformation of business procedures [18], in which soft skills play an important role: leadership, conflict resolution, and communication [19,20], as well as educational activities for the team [21].

The modern construction industry is undergoing a paradigm shift in which BIM methodology, despite its widespread use, is beginning to reveal significant limitations [3,4,22]. Although ISO 19650-1:2018 defines BIM as the organization and digitization of information about construction objects, emphasizing a structured *Common Data Environment* (CDE) [23], the literature on the subject increasingly points to the reactive nature of this technology [24]. The barrier of analytical capacity is becoming a challenge, as the exponential growth of design data begins to exceed the natural capabilities of humans to reliably evaluate it. Traditional BIM models, limited to reflecting the current state and managing data without verification, document decisions rather than initiate them, which, in the face of increasing project complexity, becomes a barrier to process throughput [22]. In this context, the role of the BIM Manager, which has evolved from that of a technical coordinator to an information strategist, faces a new challenge [7,11]. The essence of the change is no longer just maintaining a digital twin, but implementing systems capable of autonomous reasoning, prediction, and adaptation. Current work standards are only the foundation of a new era in which the Manager manages not geometry, but generative algorithms and the intellectual capital of the organization [25]. An analysis of the literature and market practice indicates that the future role of the BIM Manager is determined by the integration of advanced artificial intelligence (AI) algorithms, which will take over the operational aspects of model management [26]. As a result, the profile of this position is evolving from technical coordination towards data system architecture and business strategy [7]. The aim of this study is to demonstrate that without a solid process foundation based on standards such as the multi-part ISO 19650 standard [23], the implementation of AI technology carries a high risk of failure, and that soft and leadership skills are an essential element for the success of this transformation [27].

2. Materials and methods

The research process was divided into three stages, including an analysis of theoretical foundations, a synthesis of the literature on the subject, and the development of projections for the role of the BIM Manager in the context of digital transformation. In the initial phase, four key areas of professional activity were identified, including the strategic, process, technological, and social dimensions. This typology, resulting from an analysis of the ISO 19650-1:2018 standard and current market practice, served as the structural basis for further selection and analysis of sources. The second stage involved a narrative review of scientific literature, which collected over 100 publications on BIM, data engineering, and the implementation of artificial intelligence in the construction sector. The review was not designed as a systematic review following a formalized protocol (e.g., PRISMA), but rather as a structured, expert-driven exploration of the field, guided by the authors' professional experience in BIM management and informed by the thematic framework defined in the first stage.

The sources were indexed in a proprietary database, assigning each item to at least one of the four areas mentioned above and to a category covering current practices, best practices, or future practices. The literature was collected primarily from the Scopus and Google Scholar databases, supplemented by recognized industry standards (ISO 19650 series), institutional guidance documents (e.g., UK BIM Framework), and selected monographs. The search was conducted using keyword combinations including 'BIM Manager', 'Building Information Modeling AND artificial intelligence', 'digital twin AND construction', 'generative design AND BIM', and 'openBIM AND interoperability'. The temporal scope was not rigidly defined but focused predominantly on publications from the period 2018–2025, reflecting the post-ISO 19650 era of BIM standardization. Inclusion criteria favored peer-reviewed journal articles, conference papers, and recognized standards addressing BIM management, AI integration, or the evolving role of BIM professionals. Sources not available in English or Polish, as well as publications lacking direct relevance to the defined thematic areas, were excluded. The initial corpus of over 100 identified sources was subsequently narrowed through qualitative assessment of relevance and thematic fit, resulting in the final set of 49 references cited in this paper. The system used made it possible to identify the trajectory of the evolution of the manager's role and diagnose gaps in current standards. This reduction reflects the qualitative filtering process in which sources were assessed for thematic relevance, methodological rigor, and contribution to the identified research dimensions. In selected cases, artificial intelligence models (Gemini 3.0 Pro, Claude Sonnet 4.5) were used to extract key text fragments and identify the most important theses of the authors. The use of AI was supportive in nature and did not replace the critical substantive assessment carried out by the authors. A key element of the analysis was the identification of the cognitive gap as the main challenge of contemporary BIM practice. This phenomenon, defined as the disproportion between the exponential growth of design data and the linear limitations of human perception, served as a reference point for assessing the adequacy of current working methods and justifying the need to implement AI-based solutions. The final stage involved formulating forecasts for the development of the role of the BIM Manager. Based on an analysis of technological trends and scientific research directions, priority transformation trends were identified, consisting of a shift from traditional modeling to generative design and from reactive to predictive management, with a simultaneous evolution of graphical interfaces towards conversational solutions. The analysis also covered the concept of digital twins and the use of augmented reality technology in the process of project verification and data quality control.

It should be explicitly noted that this study is conceptual in nature and does not present empirical case studies, experimental investigations, or numerical simulations. The findings and projections are derived entirely from the synthesis and interpretation of previously published research. Accordingly, the conclusions should be understood as conceptual interpretations of identified trends rather than empirically validated results.

3. Results

3.1. Fundamentals of digital hygiene

A prerequisite for the implementation of advanced autonomous systems based on artificial intelligence is mastering the basics of information management referred to as digital hygiene, which is a set of data management practices, including structuring, verifying correctness, and ensuring consistency in accordance with the multi-part ISO 19650 standard. A review of the literature indicates that the most common cause of failure in digitization is not a lack of technology, but disorganization in the area of processes and data [27]. The modern BIM Manager must therefore move away from the role of software operator to that of an information ecosystem architect. It is worth noting that the BIM model is not an autonomous creation, but rather the result of business strategy, process rigor, and organizational culture [28]. Without precisely defining business objectives using *Organizational* Information Requirements (*OIR*), even a technically perfect model becomes useless in the operational phase [8]. The main challenge is therefore to move from unstructured file exchange to structured data flow. This requires consistent implementation of the ISO 19650 standard, which enforces a systematic approach to naming, statuses, and responsibilities. Only in an environment where data is unambiguous and verified (*Single Source of Truth*) [26,29] is it possible to apply automation. Without these standards, AI algorithms will only replicate human errors at a faster rate (the *Garbage In, Garbage Out* principle) [41]. Table 1 summarizes the most important areas that form the foundation of the technological changes taking place.

Table 1. Synthesis of BIM best practices in a multidimensional approach, covering strategic, process, technological, and social dimensions. Source: own elaboration based on [8,13,14,17,26,28–32]

Dimension	Key actions and standards	Reasoning
STRATEGIC	Definition of information requirements (OIR, AIR – Asset Information Requirements, EIR – Exchange Information Requirements). Adapting standards to legal requirements and organizational business goals. Translating investor goals into technical language.	Implementation effectiveness depends on precisely defined business goals, not just the technology itself. Early definition of requirements prevents the cognitive gap and data waste.
PROCESS	Model coordination and merging in CDE. Verifying compliance with the BIM Execution Plan (BEP). Managing information exchange and data transfer according to the ISO 19650 standard series.	A structured CDE as a *Single Source of Truth* is critical for avoiding errors. The BEP should not be a static document, but a flexible set of operational guidelines.
TECHNOLOGICAL	Interoperability control (openBIM). Utilization of IFC (*Industry Foundation Classes*) / BCF (*BIM Collaboration Format*) formats, control of parametric standards, and the use of model simulations and analyses.	Interoperability ensures data longevity and vendor independence. It is a prerequisite for creating an ecosystem of connected cloud applications.
SOCIAL	Change management and resistance reduction. Coordination of interdisciplinary communication (e.g., Big Room sessions), competency support, and internal team training.	BIM implementation is a process of cultural change. A leader's soft skills are essential for overcoming resistance to change and building trust, which digital tools alone cannot provide.

The presented structure of processes and data, although indispensable, leads to a paradoxical effect. Organizations that have implemented digital hygiene standards, such as CDE or the ISO 19650 series of standards, have developed a formalized digital structure in which information flow is orderly, but the decision-making process remains static and fully dependent on human analytical abilities [23]. The contemporary paradigm of operation, referred to in the literature as data-*informed* [4,24], assumes that decisions are made by experts based on the reports provided. However, specialists point out that without precisely defined business objectives and data processing strategies, technical solutions alone are only a financial burden instead of building real value for the company [8].

3.2. Cognitive gap

The growing complexity of investment projects makes the barriers to their implementation increasingly difficult to overcome. The exponential growth in the amount of data generated by modern investments, from laser scanning to readings from thousands of *Internet of Things (IoT)* sensors, means that traditional methods of analysis are no longer sufficient [26]. An important dilemma remains: whether the implementation of new AI-based tools will solve this problem or lead to information noise, where data overload will paralyze the decision-making process [4]. This discrepancy between data growth and the ability to analyze it is defined as the *Cognitive Gap*, which describes a situation in which the amount of incoming information exceeds the natural capacity of the human mind to reliably evaluate it and draw accurate conclusions. The illustration of this phenomenon shown in Fig. 1 is based on Martec's law, according to which technology changes exponentially, while organizations and human adaptive capacities evolve much more slowly, i.e., at a logarithmic rate. This figure shows two divergent trajectories: the exponential curve of growth in design and operational data (*Big Data*) and the linear and asymptotic curve of human analytical capabilities [42,43]. The area between these curves is a risk zone where critical errors and suboptimal decisions go unnoticed [44]. Given the scale of the challenges, traditional computational methods and expert judgments are giving way to AI-supported solutions [33].

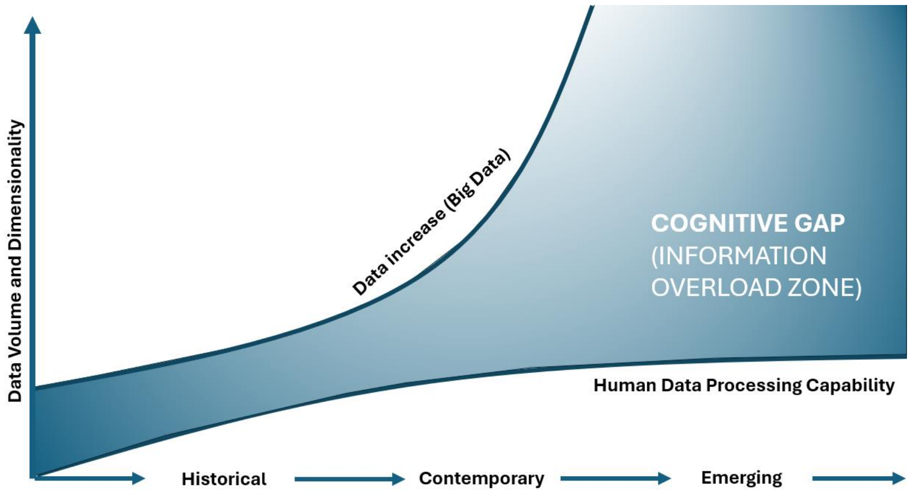

Fig. 1. Conceptual illustration of the cognitive gap between technological progress and organizational adaptation capacity, based on Martec's Law [42,43]. Source: own elaboration

However, the main obstacle to this transformation is a systemic skills gap that arises at the intersection of civil engineering and computer science [45,46]. The traditional model of educating civil engineers, focused on statics and building physics, does not equip graduates with the skills necessary to manage complex data sets (*Data Science*). This results in a shortage of personnel capable of critically verifying the results generated by artificial intelligence algorithms [45,47]. The failure to quickly adapt curricula or implement intensive retraining processes within organizations leads to a situation where advanced digital tools will be operated by personnel who are not qualified to assess their correctness [46]. This situation creates a direct risk of large-scale design errors. It should be assumed that the implementation of artificial intelligence alone is not the answer to productivity stagnation. Historical analogies indicate that the mass computerization of recent decades has not translated into a surge in efficiency in the construction industry, as confirmed by research on the phenomenon known as *the Productivity Paradox* [24]. Imposing advanced algorithms on inefficient manual processes will only accelerate the generation of erroneous data without addressing the diagnosed cognitive gap [34,47]. To exceed this efficiency threshold, a fundamental transformation of the way information is structured is necessary. A prerequisite is to change the data format from human-readable, including static documentation such as inactive PDF files, scans, or traditional CAD drawings without metadata, to *machine-readable* data [4,45]. Structuring information based on ontology and semantics allows for the creation of an environment in which IT systems are no longer limited to reporting past events [22], but begin to actively support the control of the entire investment process [4]. These changes force the evolution of the role of the BIM Manager from that of a tool operator to that of a system designer responsible for ensuring that data is understandable to algorithms [14,35].

4. Discussion

A significant transformation in BIM Manager work standards is currently occurring as a result of the integration of data engineering and artificial intelligence. This evolution is leading towards autonomous systems in which the role of humans is shifting from operational data processing to strategic management of data streams. Future practices will be defined by a paradigm shift from a data-supported approach to a *data-centric* model. Under this concept, decisions are made based on complete, machine-readable sets of information available in real time [4].

4.1. Data flow optimization. From open standards to artificial intelligence

The fundamental basis for future practice is a thorough change in the way we communicate with digital systems. The success of these changes does not depend on costly and closed ecosystems from a single manufacturer, but on the strategic use of open standards as a language for artificial intelligence. AI models learn most effectively from structured data [26], which is why the IFC format and the *Information Delivery Specification* (IDS) standard can become a universal communication protocol between algorithms and building models [25,35]. In practice, this means that the BIM Manager changes the scope of activities, abandoning manual verification of geometric model compliance. Instead, they define IDS files that act as machine instructions, precisely specifying information requirements. This enables systems to autonomously verify the completeness and correctness of data [35,36]. This mechanism enables a transition from random verification to continuous, automatic quality auditing performed in real time with each model update. This process is supported by cloud-based CDE platforms, where data integration and processing are centralized, ensuring accessibility for all stakeholders and eliminating isolated data sets [25]. The optimization of data flows is changing the way we interact with software, leading to the gradual marginalization of the traditional graphical user interface (GUI). As BIM models transform into semantic databases, manual manipulation of geometry is becoming an inefficient process [4,22]. *Conversational* UIs, based on private Large Language Models (LLMs) trained on historical enterprise design assets, are expected to gain prominence [22]. This evolution promotes the democratization of access to information, as data previously reserved for industry specialists becomes available to stakeholders without technical knowledge through queries formulated in natural language (so-called prompts). In order to maintain consistency with the philosophy of open standards, the use of API aggregators, such as OpenRouter, is becoming increasingly important. These tools perform a function analogous to the IFC format in the geometric layer, acting as a neutral intermediary layer that eliminates the risk of *vendor lock-in* [14,35]. This allows for flexible selection of a model tailored to the specifics of a task and secure implementation of *open-source* solutions in private infrastructure, which is essential for protecting a company's intellectual property. In the presented model, the role of the BIM Manager is evolving towards a function referred to as Knowledge Engineer, who designs ontologies and concept dictionaries. These give data a semantic structure, thanks to which artificial intelligence algorithms correctly interpret the design context and can autonomously manage the flow of information [22].

4.2. Algorithmic design and predictive management

Organ*izing* the data layer enables a profound transformation of the value creation methodology, in which traditional modeling is replaced by generative *design*. Machine learning algorithms can explore thousands of architectural variants in minutes, optimizing them for material costs, energy efficiency, and carbon footprint [24]. In such a structured environment, the role of the BIM Manager is evolving towards that of a supervisor and verifier who defines boundary parameters and evaluates AI system proposals, rather than creating geometry independently [37]. An essential element for implementing these innovations is the support of management. Research shows that prioritizing BIM methodology in sustainable projects by the board and top management is a decisive factor in the successful integration of technology with project objectives [8,38,39]. At the same time, the use of predictive analytics enables a shift from reactive to preventive management. Algorithms analyze historical data, forecasting the risks of delays and budget overruns with high precision, allowing for early identification of threats [33,37]. This potential is even more evident in the operational phase, where AI systems integrated with HVAC installations can reduce energy consumption by 25% and, in the area of maintenance, predict infrastructure failures with high predictive accuracy [26]. This allows for completely autonomous facility maintenance planning before a physical failure occurs. *Computer* vision technology, on the other hand, enables automatic comparison of point clouds from laser scanning or construction site photos with a BIM reference model [4]. These systems detect construction deviations and collisions already at the implementation stage [46]. Studies show that early error detection can substantially reduce post-construction repair costs [47]. Algorithms that analyze *occupancy data* also enable dynamic reorganization of office layouts based on actual user behavior, eliminating the need to rely solely on design assumptions [10]. As part of these activities, the BIM Manager becomes a strategist who uses algorithmic predictions to optimize the life cycle of a facility and ensure its continuity of operation.

4.3. From a static model to a dynamic operating environment

The described changes in the data structure enable the transformation of the BIM model from a passive repository into an active *Building* Operating *System* (BOS). In this concept, the model ceases to be merely a digital archive of documentation and becomes a central integration platform, connecting the hardware layer, i.e., sensors and IoT devices, with management software [4,10]. This mechanism forms the foundation for the *Active BIM* concept. Unlike a static design model, *Active BIM* functions as a dynamic knowledge base fed by real-time data streams, allowing for ongoing monitoring of the building's life cycle [6]. Thanks to its integration with FM-class systems, this model not only collects information about the technical condition but also provides a semantic framework for interpreting sensor readings [14,44]. This solution allows for real-time interpretation of data flowing from the building and two-way communication between the Digital Twin and the physical infrastructure [4,44]. In a broader context, the Digital Twin serves as a testing environment for autonomous AI decisions and is used as a secure simulation platform. Before the system makes an autonomous decision to change the building's operating parameters, such as adjusting the air conditioning to the forecast weather, it first simulates its effects in a virtual replica of the facility [10]. The model integrates data from IoT sensors and management systems within *a* higher-level *System of Systems (*SoS) [28], ensuring synergy and the achievement of complex goals that would be unattainable for separate installations. These technologies create a living Active BIM model capable of responding to changing environmental conditions [6]. In this ecosystem, the role of the BIM Manager takes on priority importance for process safety. Their responsibilities include designing the logic of data flow between the physical and digital worlds, ensuring the semantic correctness of information, and defining test scenarios for algorithms. Without proper human supervision, the autonomy of systems remains illusory and potentially risky [7].

4.4. Verification in reality. AR as a control tool

Immersive technologies, which include virtual reality and augmented reality, defined as VR and AR, are an important complement to digital processes, serving to validate design assumptions in the physical world [39]. As part of these solutions, AR technology transfers the BIM model directly to the construction site and allows the designed geometry to be superimposed on the actual state. This allows for immediate verification of work progress along with the identification of deviations *in situ*, which translates into an increase in engineers' understanding of the project by up to 20% [40]. An important feature is the introduction of two-way information flow. Modern AR systems, in addition to project visualization, enable immediate reporting of irregularities [40]. Identified collisions or execution deviations can be annotated digitally and sent back to the CDE environment using the BCF standard [35]. This process provides the BIM Manager with access to structured data from the construction site in real time, which enables full integration of quality control processes and eliminates analog reporting methods. The use of these technologies also extends to the facility operation phase. AR systems integrated with COBie (*Construction Operations Building Information Exchange*) standard data allow for nearly 100% accuracy in maintenance tasks, eliminating interpretation errors by visualizing instructions directly on the employee's devices [15]. For the BIM Manager, this means responsibility for ensuring the high precision and timeliness of the model so that field teams can rely on it in real time. These activities lead to strengthening the role of the model as a Single Source of Truth, which supports the work of designers and provides an information base for executive staff.

4.5. The new role of the BIM Manager. From operator to knowledge architect

In the context of intensive automation development, the BIM Manager is transforming into a specialist performing the role of Knowledge and Semantics Engineer or BIM Ontology Architect. Their primary responsibility is no longer file management, but rather building a corporate knowledge base and training AI algorithms based on the specific design characteristics of a given organization [22]. This entails a shift from verifying geometric collisions to validating the business logic contained in models, which prevents the duplication and perpetuation of human errors by machine learning systems. This role is also evolving towards that of *a* BIM *Developer*, which allows the company to become independent of the rigid framework of commercial software through its own research and development activities [21]. As a result, the organization ceases to be a passive consumer of ready-made solutions and gains technological independence, translating its unique experience into proprietary scripts and procedures. This change forces a redefinition of the necessary competencies [12]. In addition to traditional engineering skills, proficiency in data analysis tools such as SQL for database management and Python for process automation is becoming a priority. This requires a unique combination of technical knowledge, data science competencies, and leadership skills that are essential for effective digital transformation [31]. In the model of cooperation with artificial intelligence, the BIM Manager acts as the ultimate verifier, operating in accordance with the human-in-the-loop model. They define the success criteria for algorithms and audit their results, remaining the final decision-making authority. This allows for the consideration of design conditions that the systems cannot interpret on their own [47,48]. The engineer supervises the logic of operations and verifies the final results, which guarantees process safety and minimizes the risk of system errors [22,47,49]. Ultimately, the BIM Manager becomes a strategist managing the intellectual capital of the company. He or she is responsible for ensuring that information is treated as an important investment resource [8]. Thanks to this approach, with each subsequent project, the data increases the predictive and generative potential of the organization, instead of becoming a useless collection of information. A complete synthesis of the areas described, providing a graphical summary of the evolution of the manager's role and the accompanying technological changes, is presented in the diagram below (Fig. 2).

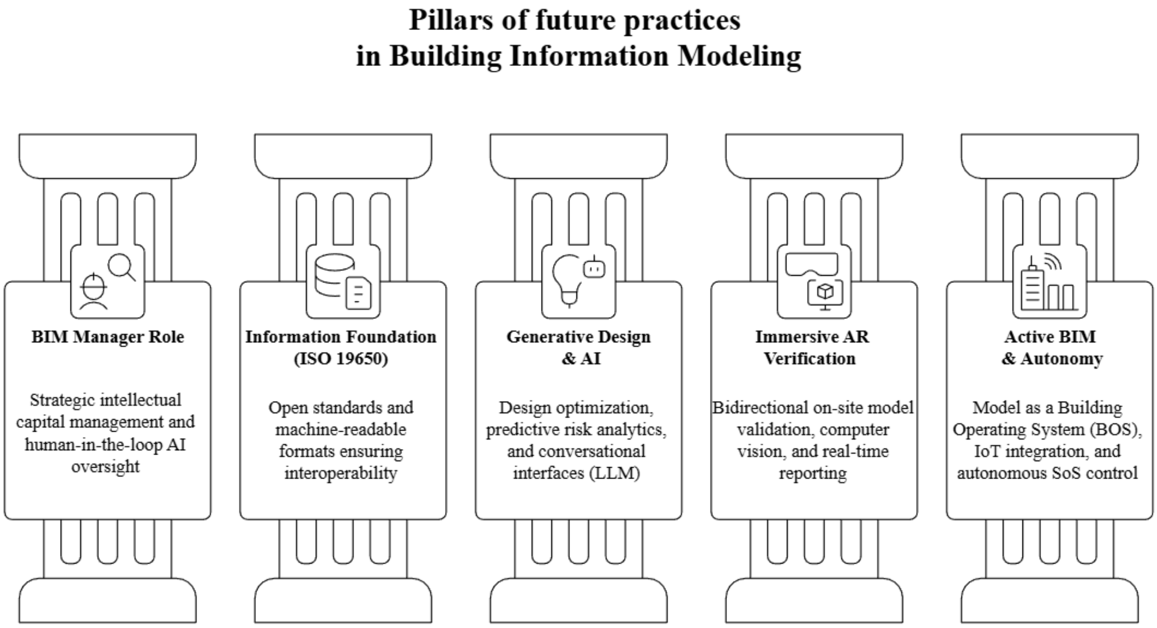

Fig. 2. Conceptual framework presenting the five pillars of future BIM practices: data flow optimization, algorithmic design, dynamic operating environment, AR verification, and the redefined role of the BIM Manager. Source: own elaboration

5. Conclusions

The current role of the BIM Manager is at a critical juncture, resulting from the cognitive gap between the exponential growth of data and the natural limitations of human perception. The existing model of work, based on manual coordination and a reactive approach, is no longer sufficient in the face of the growing complexity of investments. The considerations carried out proved, in accordance with the objective of the study, that the basis for further development is not the implementation of algorithms alone, but the implementation of rigorous digital hygiene based on the ISO 19650 series of standards. Converting data into a machine-readable format is an essential step, without which artificial intelligence, instead of supporting decision-making, will only replicate existing errors on a larger scale. In such an environment, future practices will be shaped by the synergy of three main technological domains. Open standards are no longer just exchange formats, but are becoming a universal tool for artificial intelligence systems that relieve humans of the burden of analysis and design variant generation. An important element of this system is immersive technologies, in particular augmented reality, which ensures the continuity of quality control processes through two-way verification of digital assumptions in the physical world.

According to the presented forecasts, the professional identity of the BIM Manager is undergoing a profound transformation, evolving from the role of a technical model operator to that of a knowledge management strategist and digital transformation leader. This means a significant shift in emphasis from software proficiency to the ability to strategically manage an organization's intellectual capital. This analysis confirmed that soft and leadership skills are the foundation for the success of this change, as technology alone cannot overcome process resistance without proper leadership. The outlined vision of the future is polarized, as it poses a real threat of professional marginalization for specialists who limit themselves to manual tool-based work. On the other hand, supporters of digital transformation are presented with a scenario in which the same technology becomes an instrument for promotion from the executive level to decision-making structures. It should be noted that even in the face of advancing autonomy, it is crucial to base systems on the *human-in-the-loop* model, in which humans remain the superior link in the decision-making loop and the ultimate verifier of the safety and ethics of algorithmic actions. The consequence of this change is the need to abandon the static model of engineering education in favor of a model of continuous education needed to bridge the competence gap. The ultimate question, therefore, is not about the survival of the role itself, but about the industry's readiness to accept a new model in which managers manage not geometry, but logic and the supervision of autonomous processes.

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