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Development of a Digital Governance Method for BIM-Based Design of Support and Fastening Systems for HVAC Installations According to ESG Principles

Dina Khaliullina[1*]

[1]Independent Postgraduate Researcher, Moscow State University of Civil Engineering (MGSU), Germany

Abstract. The paper presents a digital governance methodology for managing large-scale Building Information Modeling (BIM) projects based on Environmental, Social, and Governance (ESG) principles. The proposed method is applied to the coordination and modeling of support and fastening systems for Heating, Ventilation and Air Conditioning (HVAC), piping, and structural elements. It creates a resilient organizational environment where project performance is independent of individual presence. Through transparent role distribution, unified rules, and standardized data exchange, any engineer, including team leads, can temporarily leave the project without risk to quality or deadlines. The approach supports inclusion and diversity by enabling English-language communication and equal access to project information. At the same time, it reduces the consumption of time, human, and computational resources, contributing to overall sustainability and lower carbon footprint. The methodology integrates a Design Core system, unified Search Sets in Navisworks, and a digital General Rules database, ensuring consistent knowledge flow and rapid onboarding. The presented approach demonstrates how ESG principles can be practically embedded into BIM-based coordination of support nodes and installation systems, enhancing digital efficiency, social balance, and responsible resource use within the construction industry.

1 Introduction

In BIM-based design and subsequent modeling of support and fastening systems for HVAC installations, project teams frequently face financial and technical challenges [1]. These include defining realistic delivery schedules, estimating workforce requirements, calculating labor hours, and managing project costs. Companies increasingly seek to reduce expenses, accelerate decision-making processes, and maintain control over budget deviations arising from design errors or late client-driven changes.

A major technical challenge is the variability in competence levels among BIM engineers and modelers. Team composition often changes: some specialists leave the project, others

* Corresponding author: khaldin.global@gmail.com

join, and the team must quickly adapt. In practice, when a highly competent BIM engineer is on sick leave or vacation, the remaining team members may lack technical supervision, overlook complex multi-support zones, or postpone decision-making.

Additionally, BIM managers frequently delegate onboarding of new team members to the most experienced BIM engineer, significantly increasing that engineer's workload and raising the risk of technical mistakes. Customer changes are distributed across the team and must be implemented under tight deadlines, contributing to operational stress and inconsistency in design quality.

As a result, in many standard BIM projects, roles and responsibilities remain vague. Typical formulations such as "the BIM Manager is responsible for deadlines, the BIM Engineer for design, and the modelers for model quality" do not provide actionable guidance. This ambiguity leads to inefficient resource allocation, formation of unbalanced teams, reduced psychological safety, and burnout among technical specialists. From an organizational viewpoint, the lack of transparent workflows contradicts ESG principles, particularly those related to governance, environmental responsibility, and social well-being [2, 3].

The aim of this paper is to propose a digital governance method for BIM-based design of support and fastening systems for HVAC installations aligned with ESG principles. Establishing a transparent, structured, and digitalized workflow is critical for ensuring that each team member understands their scope, schedule, and responsibilities. The need for such digitalization continues to grow, especially in the context of HVAC support installation, where multiple subcontractors may be involved and replaced during the construction lifecycle of large-scale projects [4].

Reliable design of HVAC support and fastening systems is particularly important in industrial facilities, medical buildings, and data centers, where numerous pipes, ventilation ducts, and sprinkler systems compete for limited space. High-rise buildings—common in the United States, Europe, and Asia, often exceeding 25–30 floors—require full BIM coordination, forcing BIM engineers to design complex support systems for vertical shafts, including fixed and sliding supports, or 3D support structures where shafts lack reinforced concrete walls. Ensuring constructability and accuracy of delivered materials becomes a major challenge [5].

These complexities underline the necessity of optimizing both managerial and technical processes within BIM projects in accordance with ESG principles [6]. A structured digital governance model can enhance transparency, reduce errors, support human-centered work environments, and enable sustainable, efficient, and well-governed project delivery.

2 Methods

2.1 Clear Scope Allocation Model

Prior to the start of the design phase, the project must be divided into clearly defined zones, distinguishing areas that are critical for the client from those that may be completed after delivery of the main project scope. In professional terminology, this structuring corresponds to a framework-based approach.

For high-rise buildings, such zones typically include heat substations, pump rooms, podium levels, and technical floors. In industrial buildings, these are groups of rooms containing equipment with high engineering density, such as areas with extensive HVAC systems, temperature-controlled piping, cable trays, ventilation networks, and fire protection pipelines. In contrast, standard typical floors in high-rise buildings can be efficiently executed through replication of a predefined Design Core.

Within this approach, two distinct design categories are identified:
- Design Specific, where the BIM engineer is required to design customized HVAC support and fastening nodes for complex engineering systems, perform structural calculations, and provide precise technical instructions to modelers;
- Design Core, which consists of standard, pre-calculated fastening solutions commonly available in manufacturers' catalogues of installation systems. These include typical supports such as single supports (anchors, threaded rods, clamps), pipe and duct trapezes, frames for pipelines [7, 8, 9]. The defining characteristic of Design Core elements is their standardized nature and high degree of repetition.

Based on this differentiation, BIM-related tasks can be systematically distributed as follows:
- Junior BIM Engineer is responsible for designing HVAC fastening systems on typical floors by applying Design Core solutions derived from installation system manufacturers' catalogues or from a standardized internal booklet, the structure of which is described in Section 2.2;
- BIM Engineer performs design work in technically complex zones such as heat substations, pump rooms, and technical areas, where load calculations for supports are required, along with the preparation of clear and structured instructions for modelers working with multi-support systems or 3D support assemblies;
- Senior BIM Engineer is responsible for identifying project areas that require different levels of BIM engineering involvement based on their technical complexity. Within task definitions, the Senior BIM Engineer specifies special regulatory requirements (e.g., fire-rated corridors), client-specific preferences for HVAC fastening systems, and other critical constraints. The primary responsibility of this role is not direct design work, but rather quality assurance of engineering solutions, followed by verification of correct BIM modeling implementation.

This structured allocation of responsibilities ensures clarity of scope, reduces dependency on individual expertise, and establishes a resilient and scalable BIM governance framework aligned with ESG principles [2].

2.2 Design Core Booklet for Repetitive Solutions

The standard HVAC support solutions are typically presented in the catalogues of installation-system manufacturers [9]. These catalogues specify point loads for pipes and uniformly distributed loads for ducts, together with the corresponding suitable profile sections, for example for trapeze hangers. At present, many manufacturers have already developed and implemented basic BIM support families; others maintain internal catalogues containing the most frequently recurring solutions, which modelers can directly apply without the involvement of engineers.

All of this represents a significant advantage and leads to the fact that the Design Core booklet is commonly reused from project to project, often in an unchanged form and without prior analysis.

However, within the ESG-oriented project governance framework, it is preferable that the Senior BIM Engineer, after completing the Framework phase and during scope definition, develops a project-specific Design Core booklet. Naturally, the standard Design Core booklet should be used as a basis – but all elements unrelated to the project should be removed, and frequently recurring solutions should be added. For example, this may include multi-support assemblies where several ducts pass above and 1–5 pipes run below, or, for instance, repetitive configurations where multiple cable trays are installed adjacent to pipelines.

At this stage it is essential to consider the client's expectations and clarify which types of solutions are preferred – whether multi-support assemblies are acceptable, or whether each system must be supported independently. It is also necessary to identify which project areas may utilize standard support assemblies that can be assigned to a Junior BIM Engineer.

This approach increases project controllability and enhances the transparency and documentation of engineering and modeling processes [10].

2.3 Unified Search Sets for Multidiscipline Coordination

In modern BIM-based design of support and fastening systems for HVAC installations, it is highly beneficial to define search sets even before the start of the engineering phase [11]. Using the Find Items and Search Sets tools, it is possible to group and isolate various structural and architectural elements such as load-bearing walls, raised floors and ceilings, steel structures, composite shells, and façades. For MEP systems, dedicated search sets may be created for piping systems, ventilation, smoke extraction, and different insulation types, as illustrated in Figure 1 for one of the reference projects.

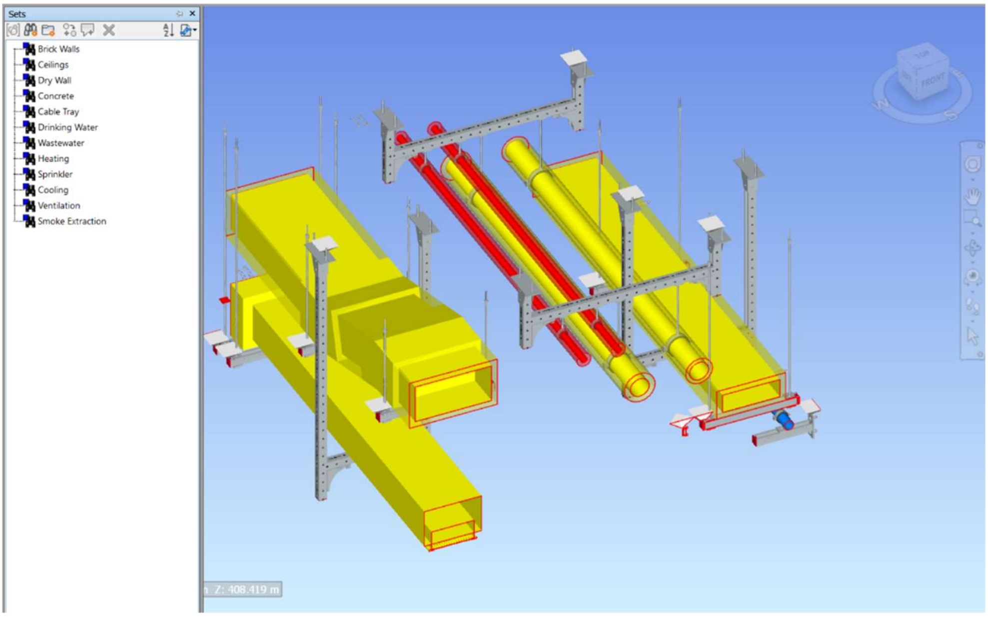

Fig. 1. Unified Search Sets for Multidiscipline Coordination.

Working with unified search sets across the project enables even newly-onboarded BIM engineers to immediately assess design scope and estimate required effort. This allows, for example, to highlight systems that need to be launched and hide those that are not within the scope of application.

By using the Sets and Hide Unselected functions, the heating system and its related support assemblies can be isolated and visually inspected. This allows BIM engineers to verify whether all required support elements have been modeled and whether the spacing between supports complies with design specifications.

These tools may be used not only by BIM engineers but also by modelers. Throughout the project lifecycle, new search sets may be added, supporting efficient coordination and simplifying daily workflows for all project participants.

2.4 Detailed General Rules Workflow

In each project, specific configuration requirements apply. For example, in technically complex dairy factories there are many large-diameter pipes operating at high temperatures, while hospitals contain pressurized medical gas pipelines, and so on. Every pipeline has its own manufacturer and corresponding regulations regarding pipe supports. The responsibility of the Senior BIM Engineer is to identify these characteristics and to develop an appropriate General Rules document for engineers and modelers. This document must specify special installation requirements, define the support concept (fixed, sliding, and standard supports), and set maximum support spacing.

In most cases, a standard General Rules document already exists. Therefore, the main task consists in adding supplementary data that is relevant to the particular project.

According to Figure 2, during the project lifecycle the General Rules document is continuously updated and harmonized, since important information is provided by all stakeholders, including both BIM engineers and modelers. Working within their respective responsibility areas, BIM engineers identify recurring specific situations and communicate them to the Senior BIM Engineer, who updates the General Rules after review and approval. Modelers may also submit frequently recurring questions, for example regarding the allowable distance between pipe supports before and after a fire-rated wall. These questions are forwarded to BIM engineers, and the corresponding permitted ranges are incorporated into the General Rules.

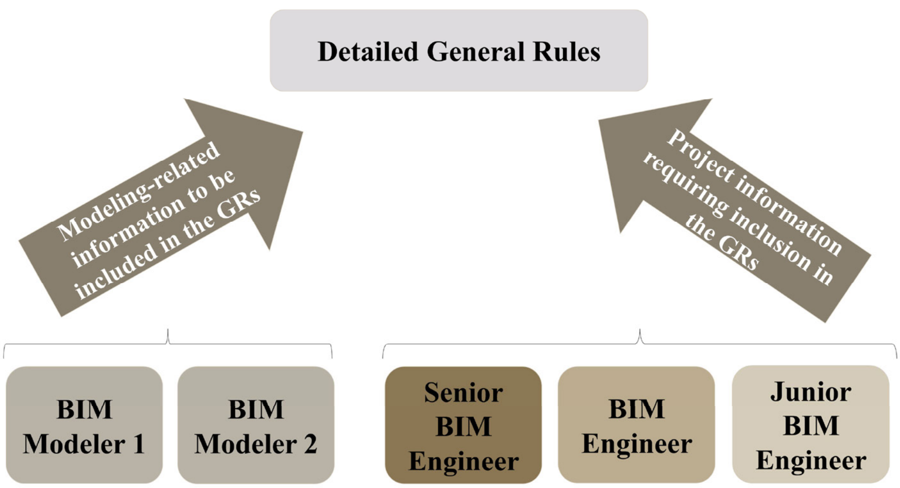

Fig. 2. Detailed General Rules Workflow.

This approach ensures project resilience and operational continuity. When a team member leaves the project, regardless of their role, the workflow is not interrupted, because the General Rules are predefined and systematically managed from the outset [12].

2.5 Performance-Based KPI for Change Request Management

In the classical BIM project structure, workload and responsibility are very often transferred from top to bottom, which contradicts ESG principles. Responsibility for change requests is frequently overlooked. Clients often have no motivation to approve the final project version, as they are paying for the service. In most cases, the client is not concerned whether the allocated budget is sufficient to complete the project, especially when managers promise unrealistic outcomes at the early project stages.

As a result, it becomes a major challenge to hire truly experienced BIM managers with an understanding of both Project Management Professional fundamentals and the technical specifics of BIM-based projects. This situation highlights the necessity of introducing a Key Performance Indicator (KPI) parameter linked to annual bonus compensation, aimed at managing client-driven change requests.

For example, the performance-based compensation model may consist of two components:
- 80% fixed salary;
- 20% variable bonus (B).

The variable component is calculated according to Equations (1)-(3), based on the percentage of change requests caused by managerial errors (CP), measured through issues recorded in the BIM tracking environment. A higher percentage of changes corresponds to a lower bonus, while a low change ratio indicates effective upstream coordination and results in a higher bonus payout.

$$\text{Bonus}(CP) = 0 \cdot B, \text{ if } CP > 30\% \quad (1)$$
$$\text{Bonus}(CP) = 0.5 \cdot B, \text{ if } 10\% < CP \le 30\% \quad (2)$$
$$\text{Bonus}(CP) = 1 \cdot B, \text{ if } CP \le 10\% \quad (3)$$

where
Bonus(CP) – calculated bonus payout, €;
B – maximum bonus component (20% of total annual compensation), €;
CP – percentage of changes in the project caused by managerial errors, calculated using Equation (4), %.

$$CP = (N_{\text{changes}} / N_{\text{total}}) \cdot 100\% \quad (4)$$

where
N_{changes} – number of registered issues related to project changes caused by managerial errors;
N_{total} – total number of issues recorded in the BIM tracking system within the initial project scope.

When referring to change requests, it is important to clarify that only changes resulting from managerial errors are considered. These include, for example, an incorrect project or work-package start time when the client explicitly states that full input data is not yet available, but the BIM manager initiates the project or scope regardless. Changes that were previously discussed and formally agreed upon with the client are not included in the calculation.

This KPI mechanism allows responsibility to be personalized by quantifying how many issues were generated as unnecessary rework within the project during the year. The approach is based on the assumption that an effective BIM manager cannot allow a situation where a significant portion of the project requires redesign instead of ensuring clear agreements with the client at early stages.

By clearly understanding their KPI values – potentially supplemented with additional performance indicators – the manager gains full awareness of their responsibility and scope of action from the beginning of the year. This leads to the development of critical skills such as negotiation, realistic planning, and optimization of the project schedule.

From an ESG perspective, this KPI-based approach directly strengthens the Governance pillar by establishing transparent accountability, measurable managerial responsibility, and traceable decision-making processes [13]. It also indirectly supports social sustainability by reducing uncontrolled rework, operational stress, and burnout within BIM project teams.

3 Conclusions

The five methods described in this paper may be applied either jointly or selectively, depending on the specific requirements and characteristics of a given project, as determined by the Senior BIM Engineer during the initial assessment and governance planning phase.

For HVAC support engineering departments, these methods are fully aligned with ESG principles. From an environmental perspective, clearer information exchange, common General Rules, and a well-structured Design Core reduce rework and duplicated effort among team members. As a result, unnecessary iterations are avoided, which decreases time expenditure, resource consumption, and the indirect environmental footprint associated with digital and construction activities.

From a social perspective, the proposed framework enables easy onboarding, English-language workflows, and collaborative team structures that support diversity and inclusion. BIM engineers and modelers from developing countries are able to participate effectively, while responsibilities are distributed according to competence levels. This ensures fair workload allocation, supports professional development, and maintains psychological safety throughout the project lifecycle. Team members may temporarily leave or rotate between projects without operational disruption, since all design logic remains preserved within an adaptable General Rules framework. In this way, the methodology leverages the strengths of each participant while preventing excessive overload and supporting ethical working conditions.

From a governance perspective, the entire project structure becomes transparent and accountable. Responsibility for design changes is clearly defined, while the proposed management system enables rapid and traceable responses to project modifications. Senior BIM Engineers and BIM Managers retain oversight across all technical and procedural decisions, ensuring consistency and auditability.

Each of the presented methods is therefore consistent with the ESG strategy. Beyond improving day-to-day collaboration and creating a safe and resilient working environment, they also contribute to financial sustainability by reducing project delivery time, minimizing rework, and lowering operational risk. As a result, project transparency increases, client satisfaction improves, and the organizational ability to attract responsible investment is strengthened.

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