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Multidisciplinary Coordination Strategies for MEP Systems in High-Rise Construction Projects

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***Abstract*— *This article presents an analysis of contemporary approaches to multidisciplinary coordination of engineering systems in high-rise construction projects. The study is conducted in the form of a systematic review and analytical synthesis of publications devoted to Building Information Modeling, interface management, digital design coordination, commissioning processes, and engineering system integration. Particular attention is given to the relationship between spatial coordination of engineering networks, distribution of responsibilities, integrated testing procedures, and operational verification of engineering systems. The paper examines the limitations of the traditional approach to engineering system coordination, which is primarily based on clash detection. It is demonstrated that a significant proportion of coordination-related risks arise from discontinuities between engineering interfaces, inconsistencies in decisions among project participants, and commissioning-stage errors, including disruptions in the cause-and-effect logic of engineering system operation and interaction failures between ventilation, building management, and fire alarm systems. It is substantiated that effective coordination requires continuous synchronization of engineering decisions throughout the entire building lifecycle. Within the framework of the study, an original integrated model of multidisciplinary coordination for engineering systems in high-rise buildings is proposed, combining design coordination, digital model integration, interface management, construction coordination, commissioning verification, and operational synchronization of engineering information. The article may be useful for researchers in construction project management, MEP engineers, commissioning specialists, and construction project managers.*

***Keywords*— engineering systems coordination, Building Information Modeling, multidisciplinary coordination, interface management, commissioning processes, intelligent buildings, high-rise construction.**

I. INTRODUCTION

Modern high-rise buildings are characterized by a high level of engineering complexity: ventilation and air-conditioning systems, power supply, water supply, drainage, fire safety, automation, and vertical transportation systems extend throughout all building levels and continuously intersect with architectural and structural elements [2]. Therefore, the quality of such projects depends not only on spatial layouts and structural solutions, but also on how consistently engineering networks are coordinated, regulatory clearances are maintained, equipment accessibility is ensured, installation sequences are planned, and operational conditions are considered [15]. Under conditions of high communication density, traditional coordination approaches based on two-dimensional documentation, fragmented working drawings, and periodic coordination meetings no longer provide sufficient stability for the design process. Even a minor conflict between air ducts, cable trays, pipelines, fire protection lines, shafts, or floor structures may trigger cascading redesign of related disciplines, resulting in delays and additional costs [12].

Digital Building Information Modeling has significantly expanded coordination capabilities by enabling the integration of architectural, structural, and engineering models, early clash detection, and verification of spatial constraints [8]. However, the digital model itself does not guarantee coordination quality, since a substantial proportion of errors arises from fragmented collaboration among participants, inconsistent data exchange formats, weak allocation of responsibilities, and untimely updates of project information [1]. This issue is particularly critical in high-rise projects implemented in the UAE and Gulf countries, where engineering systems operate under conditions of high temperatures, dust exposure, humidity, and prolonged operational loads. Therefore, engineering system coordination should include not only verification of geometric clashes, but also management of interconnections between systems, validation of automation logic, fire safety scenarios, smoke extraction mechanisms, testing procedures, commissioning activities, and subsequent maintenance processes [18].

The purpose of the study is to develop an original model of multidisciplinary coordination for MEP systems in high-rise construction projects based on the integration of digital coordination, engineering interface management, and continuous synchronization of design, installation, and operational processes. To achieve this objective, the following tasks are addressed in the article:

– to analyze contemporary approaches to MEP system coordination in high-rise construction;

– to investigate the causes of multidisciplinary coordination conflicts;

– to evaluate the role of digital technologies in improving the efficiency of engineering coordination;

– to analyze the specific features of engineering system coordination during the commissioning stage of construction projects.

The research hypothesis is that effective coordination of engineering systems in high-rise construction projects is determined not only by the elimination of spatial clashes, but also by the continuous synchronization of design, installation, commissioning, and operational processes within a unified digital environment. In this context, the reduction of clashes represents only one of the outcomes of comprehensive multidisciplinary coordination.

The scientific novelty of the study lies in considering the coordination of engineering systems in high-rise buildings not as a task of detecting spatial conflicts, but as a continuous process of managing intersystem interfaces throughout the stages of design, installation, commissioning, and operation. Unlike the majority of studies primarily focused on BIM visualization and automated clash detection, this research emphasizes insufficiently explored aspects of coordination, including synchronization of engineering system interaction logic, integration of fire safety automation with Building Management Systems (BMS), allocation of interface responsibilities among project participants, and synchronization of engineering decisions within the conditions of high-rise construction projects in the Gulf countries.

II. MATERIALS AND METHODS

The study is based on a theoretical and comparative analysis of contemporary approaches to multidisciplinary coordination of engineering systems in high-rise construction projects. Particular attention is given to the relationship between BIM-based digital coordination, engineering interface management, synchronization of design changes, integrated testing procedures, and operational integration of engineering infrastructure. MEP system coordination is considered as a continuous process of interaction between architectural, structural, engineering, and operational solutions, in which project stability is determined by the consistency of multidisciplinary relationships rather than solely by the elimination of spatial clashes.

The study was conducted in the format of a systematic review of open-access scientific publications published between 2022 and 2025 and indexed in Google Scholar, ScienceDirect, SpringerLink, MDPI, and arXiv. The search was performed using the following keywords: “MEP coordination”, “high-rise construction”, “BIM coordination”, “OpenBIM”, “clash detection”, “interface management”, “commissioning coordination", "building services integration", "AI-BIM", and "multidisciplinary coordination". The selection included studies devoted to engineering system coordination, BIM-oriented workflows, automated verification of design solutions, integration of engineering subsystems, and management of multidisciplinary interfaces. Publications limited to the description of individual software tools without analysis of coordination processes and organizational interaction mechanisms among project participants were excluded.

At the initial stage, 52 publications were identified. After removing duplicate materials and conducting a content analysis, the final sample consisted of 20 studies reflecting the principal directions of development in BIM coordination, automated clash detection, OpenBIM interaction, engineering system integration, and coordination of integrated testing stages.

During the analysis, the following groups of factors were identified: spatial congestion of engineering zones, inconsistency between disciplinary models, fragmentation of project data exchange, weak synchronization of design modifications among project participants, and integration failures during commissioning activities. The analysis demonstrated that a significant proportion of problems in high-rise MEP projects is associated not only with geometric clashes between engineering communications, but also with insufficient coordination of interaction logic between automation systems, fire protection systems, ventilation systems, and building management systems.

The limitations of the study are associated with the predominance of analytical and review-based publications, as well as the limited number of studies devoted to engineering system coordination in the context of high-rise construction projects in the Gulf countries. The obtained results are used for the development of an original integrated model of multidisciplinary coordination for MEP systems in high-rise construction projects.

III. RESULTS

The study revealed that the increasing height and engineering complexity of modern buildings significantly complicate the coordination of MEP systems [13]. In high-rise facilities, ventilation, power supply, fire protection systems, water supply, building management systems, and vertical transportation form an integrated interdependent infrastructure in which modification of one engineering route leads to adjustments in related systems [4]. Under such conditions, a coordination error ceases to be a local issue of an individual discipline and begins to affect installation sequencing, operational accessibility of equipment, and subsequent commissioning of engineering systems.

The most critical conflicts arise in inter-floor engineering zones and technical spaces characterized by a high density of engineering communications. The reviewed publications consistently report clashes between air ducts, cable trays, fire protection lines, and pipelines within confined ceiling spaces [16]. However, the analysis demonstrates that a significant proportion of problems is caused not only by geometric collisions. In several cases, engineering systems remain spatially coordinated within the digital model but become inconsistent from the perspective of installation, maintenance, and intersystem management. This issue is particularly evident in zones integrating ventilation systems, fire automation, and building management infrastructure.

Additional complexity is created by sequential coordination schemes in which architectural, structural, and engineering disciplines are updated asynchronously. In high-rise projects, such an approach results in the accumulation of inconsistent modifications between disciplines [9]. Consequently, engineering solutions approved at earlier stages require repeated adjustments after the release of installation documentation. In practice, this leads to repeated coordination procedures, changes in installation sequences, and delays in engineering equipment delivery.

Particular importance is associated with the problem of interface dependency between engineering systems. The analysis established that the most complex coordination zones emerge at the intersection of HVAC systems, power supply systems, fire alarm infrastructure, and BMS environments [11]. Modification of one system parameter requires simultaneous adjustment of control algorithms within related engineering subsystems. Otherwise, even a spatially coordinated model cannot ensure stable operation of engineering infrastructure after the facility is commissioned. Table 1 presents a comparative assessment of the influence of traditional two-dimensional coordination and OpenBIM-oriented interaction on the principal parameters of the project process.

Table 1 – Comparative performance of traditional 2D CAD and OpenBIM-enabled collaboration (Compiled by the author based on source: [7])

Indicator	Traditional 2D CAD	OpenBIM-enabled Collaboration
Project completion time	240 h	175 h
Number of design errors	427	6
Error reduction	–	98%
Number of iterations	12	5
Average iteration duration	6 h	2 h
User experience score	6.2/10	8,7/10

The comparison of parameters reflects a substantial transformation in the structure of the coordination process when applying the OpenBIM approach. The most significant difference is associated with the reduction in the number of design errors [7]. At the same time, the number of coordination iterations decreases, and the duration of engineering solution approval is reduced. In the reviewed studies, this trend is associated with improved model visualization and more stable synchronization of engineering modifications among project participants.

At the same time, the conducted analysis demonstrates that even the use of an integrated digital environment does not completely eliminate coordination-related risks. The most complex problems continue to emerge during the installation integration and commissioning stages of engineering systems [10]. In several high-rise projects, the engineering model retains geometric correctness, while the intersystem control logic remains inconsistent. Particularly critical are smoke extraction scenarios, automatic shutdown of ventilation systems, signal transmission between fire automation and building management systems, and synchronization of cause-and-effect logic [6]. Under such conditions, the coordination risk shifts from spatial clashes between engineering routes to desynchronization of intersystem operational scenarios.

In contemporary high-rise projects, the coordination process is gradually shifting from the detection of isolated geometric clashes toward the management of intersystem engineering dependencies throughout the entire facility lifecycle [5, 19]. The digital model is increasingly used not only as a design instrument, but also as an environment for monitoring installation activities, verifying the actual condition of engineering systems, and supporting commissioning processes.

Particular importance is associated with intelligent clash filtering technologies and automated verification of design rules. In traditional practice, a significant proportion of engineering conflicts is analyzed manually, resulting in excessive workload for coordination teams due to a large number of secondary clashes [14]. In the context of high-rise construction, such conditions considerably slow down the coordination process, since even a minor modification of an engineering route may affect related systems and installation sequencing.

The role of as-built verification of engineering systems is also changing. In modern projects, the digital model is increasingly compared with the actual condition of the construction site through the use of laser scanning, cloud-based platforms, and intelligent monitoring technologies [17]. This becomes particularly important in projects utilizing prefabricated engineering modules, where deviations in installation positioning may disrupt the installation of adjacent engineering elements. Table 2 presents the distribution of digital technologies applied in the coordination of prefabricated engineering systems in high-rise projects.

Table 2 – Distribution of digital technologies in the coordination of prefabricated MEP systems in high-rise projects (Compiled by the author based on source [20])

Technology	**Number of Applications**	**Application Share (%)**	**Primary Coordination Function**
BIM	61	36,1	Spatial coordination and clash detection
IoT / RFID / QR	42	24,8	MEP systems monitoring and logistics
3D laser scanning	32	18,9	Geometric verification and installation control
XR technologies	21	12,4	Visualization and installation coordination
Robotic technologies	10	5,9	Automated installation of MEP systems

The distribution structure of technologies reflects a transformation in the very logic of engineering system coordination. A substantial proportion of digital tools is now associated not with the design process itself, but with installation control, verification of the as-built condition of facilities, and support of engineering integration. Particularly notable is the increasing role of monitoring technologies and laser scanning systems, which provide continuous comparison between the digital model and the actual state of engineering infrastructure. Table 3 presents the quantitative effects of applying intelligent BIM coordination within a multidisciplinary engineering environment.

Table 3 – Quantitative effects of AI-BIM coordination for multidisciplinary MEP environments (Compiled by the author based on source [3])

Coordination indicator	**Baseline value**	**AI-BIM result**
Design revisions per phase	12	8,4
Approval cycle duration	40 days	30 days
Geometric coordination errors	15%	4%
System clashes per project	22	3
Clash detection accuracy	–	94.7%

The obtained values are characterized by a significant reduction in the number of engineering conflicts and a decrease in the volume of design modifications. At the same time, the accuracy of critical clash detection increases. However, the conducted analysis demonstrates that the digital transformation of MEP coordination is increasingly extending beyond geometric verification. In contemporary high-rise projects, intelligent coordination is used for synchronization of installation scenarios, validation of intersystem dependencies, support of commissioning procedures, and operational verification of engineering systems. As a result, the digital model is gradually transforming from a clash detection instrument into an environment for managing engineering integration throughout the entire facility lifecycle.

IV. DISCUSSION

Coordination of MEP systems in high-rise buildings cannot be reduced solely to the detection of clashes between engineering elements. Such an interpretation is excessively narrow. It may be effective for initial geometric verification, but it does not address the actual causes of failures in complex facilities. In high-rise construction, engineering systems are interconnected not only spatially, but also through power supply logic, control algorithms, interlocking mechanisms, fire safety scenarios, equipment accessibility, and installation sequencing. Therefore, the absence of clashes within the model does not necessarily mean that the system can be correctly installed, tested, and commissioned.

Traditional clash detection identifies already existing intersections and answers the question of where engineering elements interfere with one another. However, for high-rise MEP projects, this approach is insufficient. In such facilities, the principal risk often emerges from discontinuities between related engineering solutions. For example, an air duct may be correctly positioned within the model, while its operation still requires synchronization with fire alarm systems, smoke extraction systems, building management infrastructure, and power supply systems. If this operational logic is not verified in advance, the error will become apparent later, during testing and commissioning stages.

For this reason, coordination should evolve from geometric verification toward the management of engineering interfaces. In this context, an interface is understood as a zone of responsibility and technical interaction between systems, project participants, and project stages. Within such a framework, MEP coordination includes not only routing of air ducts, pipelines, and cable trays, but also verification of how these systems interact during normal operation, emergency scenarios, and maintenance activities.

Fragmentation of workflows further intensifies this problem. Architects, structural engineers, MEP designers, subcontractors, and equipment suppliers frequently operate with different versions of project data and different documentation update schedules. As a result, decisions are made asynchronously. One discipline may already have modified the model, another may still rely on the previous version, while a third prepares working drawings based on partially outdated information. Under such conditions, even an advanced BIM environment cannot eliminate risk if there is no clear procedure for verification, approval, and transfer of design modifications [1].

The organizational dimension of coordination is no less important than the digital one. Within the multi-contractor environment of high-rise construction, engineering solutions depend on consultants, general contractors, MEP subcontractors, equipment suppliers, and commissioning teams. Each participant is responsible for a specific segment of work, yet the overall functionality of the building depends on the consistency of the entire coordination chain. Consequently, the primary weakness lies not within an isolated system, but at the boundary between zones of responsibility.

This issue becomes particularly evident during the preparation of shop drawings. Shop drawing coordination should not perform merely a formal documentation function, but rather serve as a technical filtering mechanism for engineering solutions prior to installation. At this stage, it is necessary to verify engineering network routes, equipment accessibility, connection points, supplier requirements, maintenance zones, installation tolerances, and compliance with fire safety scenarios. If such verification is performed too late, the construction site begins correcting errors that should have been resolved during the coordination stage. Figure 1 presents the author’s model of multidisciplinary coordination for MEP systems.

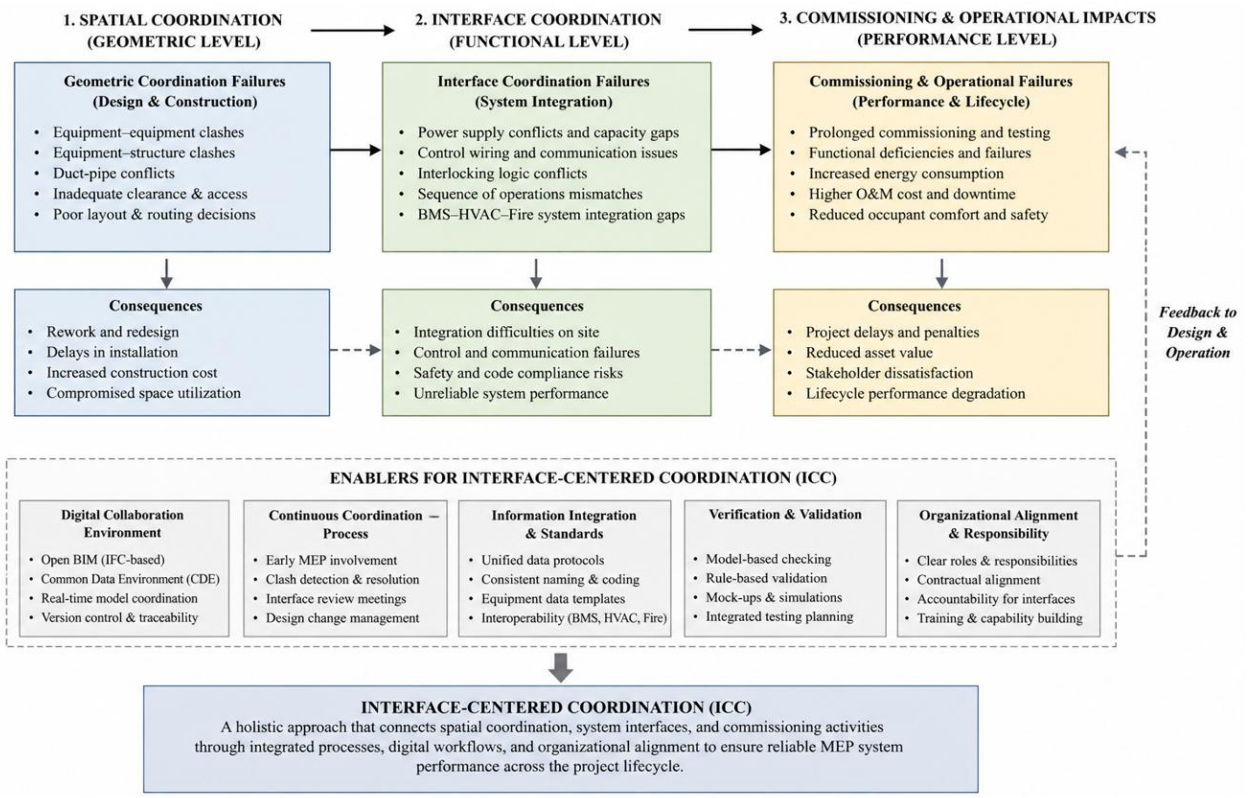

Fig.1 – Integrated multidisciplinary coordination model for MEP systems in high-rise construction projects (Developed by the author)

The proposed model considers multidisciplinary coordination as a continuous process of synchronization between design, installation, commissioning, and operation, rather than as a sequence of isolated BIM verification procedures. Its effectiveness is associated with the integration of spatial coordination, interface management, construction sequencing, and operational validation into a unified coordination environment. Such an approach reduces the fragmentation that arises when architectural, structural, HVAC, electrical, plumbing, fire protection systems, and vertical transportation are coordinated separately, followed by the transfer of decisions between different project participants without continuous control of engineering interfaces.

The model is based on the premise that coordination quality cannot be evaluated solely through the results of clash detection. In many high-rise projects, geometric clashes have already been resolved, while operational contradictions remain unresolved. For example, an HVAC system may be spatially coordinated correctly, yet still fail commissioning due to inconsistent shutdown logic, incorrect smoke extraction sequencing, or lack of synchronization between the BMS and fire alarm systems. For this reason, the proposed structure connects federated BIM coordination with interface reviews, allocation of responsibility zones, synchronization of shop drawings, integrated testing, and operational verification. Such integration ensures traceability between design decisions and the actual behavior of engineering systems during commissioning and operational stages.

The model addresses one of the most persistent limitations of multidisciplinary MEP coordination associated with asynchronous decision-making between consultants, contractors, suppliers, and commissioning teams. In practice, a substantial proportion of coordination errors arises not from limitations of BIM tools, but from fragmented workflows and delayed interface communication. The proposed structure reduces this gap by integrating coordination meetings, interface management, installation sequencing, and commissioning workflows into a single continuous coordination cycle. As a result, modifications of design solutions are evaluated not only from the perspective of geometry, but also in terms of constructability, testing logic, operational dependencies, and building lifecycle requirements.

Particular importance within the model is assigned to the integrated testing and commissioning stage. It is precisely at this stage that engineering systems begin functioning as a unified interconnected environment rather than as a collection of isolated installations. For this reason, commissioning becomes one of the most reliable indicators of the actual quality of coordination. Problems related to cause-and-effect logic, BMS–HVAC–fire integration, emergency shutdown scenarios, and smoke extraction sequencing often cannot be identified during conventional model review and become visible only during operational validation. Within the proposed model, commissioning is considered not as a final formal procedure, but as a mechanism for verifying whether multidisciplinary synchronization has been maintained throughout the entire project lifecycle.

The practical significance of the model is further strengthened by contemporary trends in digital construction. The expansion of OpenBIM environments, modular MEP systems, digital twins, IoT-based monitoring, and predictive maintenance requires coordination that continues beyond the completion of construction activities. Within this framework, the model extends coordination into the operational phase through continuous synchronization of engineering data and integration of preventive maintenance processes. This is particularly relevant for high-rise facilities in the Gulf countries, where high temperatures, dust exposure, humidity, and prolonged operational regimes accelerate equipment degradation and intensify the consequences of early-stage coordination errors.

Within this framework, multidisciplinary MEP coordination becomes a mechanism for lifecycle management of the building, integrating digital models, engineering interfaces, commissioning logic, and operational reliability into a unified coordination system. The principal factor in this context is not the number of completed clash checks, but the stability of synchronization between multidisciplinary interfaces throughout all stages of project implementation and operation.

V. CONCLUSION

The conducted analysis demonstrates that the effectiveness of multidisciplinary coordination in high-rise construction projects is determined not only by the quality of BIM models and the number of detected clashes. In most cases, the principal coordination-related risks emerge at the level of intersystem dependencies, interface responsibility zones, sequencing of commissioning procedures, and operational interaction between HVAC, electrical, fire protection, plumbing, BMS, and vertical transportation systems. Under such conditions, even a formally coordinated digital model does not guarantee stable integration of engineering systems during construction and operational stages.

Particular importance is associated with the transition from geometry-centered coordination to interface-centered coordination. In contemporary high-rise facilities, coordination should be considered as a continuous process of synchronizing design solutions, shop drawings, vendor interfaces, installation sequences, commissioning procedures, and operational validation workflows. Within such a framework, multidisciplinary coordination ceases to be solely a clash detection task and becomes a mechanism for managing engineering dependencies throughout the entire building lifecycle.

Within the framework of the study, an integrated multidisciplinary coordination model for MEP systems in high-rise construction projects is proposed. The model combines design coordination, BIM/OpenBIM integration, interface management, construction sequencing, commissioning validation, and lifecycle digital synchronization within a unified coordination environment. The central element of the model is continuous synchronization between multidisciplinary interfaces, since the consistency of decisions between disciplines determines the long-term stability of engineering infrastructure operation.

The practical significance of the study is associated with the development of coordination approaches for MEP systems in high-dependency building environments, where integration errors may evolve into operational limitations, increased reactive maintenance, reduced energy efficiency, and disruption of cause-and-effect operational logic. The proposed approach may be applied in high-rise projects characterized by a high density of engineering communications, multi-level vendor coordination, and complex integrated testing and commissioning scenarios.

Prospects for further research may be associated with the development of quantitative coordination maturity indicators, evaluation of the influence of commissioning synchronization on the long-term reliability of engineering systems, and integration of digital twins, predictive maintenance, and AI-supported coordination analytics into multidisciplinary MEP management environments.

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