2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #50637

Previous Work on the MEP E&O Problem in Concrete Slabs

Amani Qasrawi, The University of Texas at San Antonio

Amani Qasrawi is a Ph.D. candidate in Construction Science and Management at The University of Texas at San Antonio.

Dr. Tulio Sulbaran, The University of Texas at San Antonio

He received his Ph.D. in Civil Engineer from Georgia Institute of Technology with concentration in Construction Management with a minor in Computer Engineering and strong statistical background. He has over 8 years of work experience in the A/E/C (Archite

Previous Work on the MEP E&O Problem in Concrete Slabs

Amani Qasrawi[1], and Dr. Tulio Sulbaran[2]
[1, 2]The University of Texas at San Antonio, Texas, USA

Abstract

Mechanical, Electrical, and Plumbing concrete slab rough-ins are often subject to errors and omissions (E&O), which can lead to costly rework after the concrete has been poured and cured. These E&O are often discovered at later stages of the project, resulting in costly revisions that can slow progress and increase expenses. Redoing tasks that were not executed correctly the first time can significantly impact project completion time and lead to additional costs. Therefore, the aim of this study is to address the limited research on E&O in MEP rough-ins within concrete slabs. The objective is to review existing literature to better understand the scope of this issue. A scoping review was conducted, guided by the Bibliometric analysis, utilizing multiple databases (ASCE Library, Web of Science, and IEEE Xplore). The review covered the past 15 years to capture recurring challenges, patterns, and root causes, reflecting the established role of concrete in construction practices. The findings reveal a notable lack of focused research on this topic. This gap underscores the need for further investigation and for improved strategies that better prepare students for field-based inspection and coordination challenges.

Keywords:

Errors and omissions in MEP systems, Concrete slab rough-in, MEP errors in construction, MEP, Slab rough-in.

Introduction

Errors and omissions (E&O) in construction are persistent challenges that can greatly affect project quality, schedule, and cost. As construction projects become more complex, the occurrence of E&O is increasingly common [1]. Numerous studies have recognized the primary role of E&O in causing rework [2], [3], [4]. Rework has been identified as a crucial factor affecting project budgets [5].

One of the most critical yet often overlooked sources of E&O is the installation of Mechanical, Electrical, and Plumbing (MEP) systems within concrete slabs. During the rough-in phase, various embedded components, such as conduits, sleeves, drains, and anchors, must be precisely positioned before the concrete is poured. Any misalignment or omission of these elements can lead to costly rework, core drilling, or even structural issues once the slab has cured. Additionally, if these errors are not addressed properly, they can lead to long-term maintenance challenges and negatively affect building performance [6].

While previous research has examined E&O more generally within construction projects, there has been relatively little focus on the specific intersection of Mechanical, Electrical, and plumbing (MEP) systems and pre-pour concrete slab construction. Therefore, this paper aims to investigate the extent and characteristics of existing research on this topic through a scoping literature review guided by bibliometric analysis. This approach enables mapping the breadth of

available evidence, identifying key themes, and highlighting knowledge gaps that can inform future empirical and technological research. The objectives are to 1- to review published studies addressing E&O in MEP installations within concrete slabs. 2- to identify gaps in current literature and propose future research directions for improved quality control.
This research not only has technical implications but also directly impacts construction engineering and management education. While current curricula focus on BIM modeling and theoretical coordination, they lack structured training on pre-pour field verification of embedded MEP systems in concrete slabs. Recognizing this research gap highlights an educational deficiency. By understanding how E&O occur in slab rough-ins, an experiential learning module can be developed, inspection training exercises, and augmented reality–assisted instructional tools for construction students.

Methodology

This study used a scoping review, guided by the Bibliometric analysis. This approach has gained strong momentum across multiple scientific fields in recent years, including business, engineering, and construction research [8]. This growth can be attributed to the increasing availability of large scientific databases such as Scopus and Web of Science, and the availability of software tools such as VOSviewer, Gephi, and Leximancer, which allow researchers to visualize, map, and interpret large volumes of unstructured scholarly data with precision and efficiency [8].

A literature search was conducted using multiple databases, including the American Society of Civil Engineers (ASCE) Library, Web of Science, and Institute of Electrical and Electronics Engineers (IEEE) Xplore. The search used the following keywords separately: "Inspection of MEP", "QA/QC in MEP", "MEP in Field inspection", "MEP in Construction". As shown in **Error! Reference source not found.**. the initial search resulted in 959 papers; 202 duplicates were removed, and 1 paper was retracted. This resulted in a total of 756 publications.

Table 1. Keywords and Databases Used

Database used	Number of papers per keyword search	Total
(ASCE) Library	92 + 7 + 64+ 380	543
Web of Science	57 + 1 + 3+ 324	385
IEEE Xplore	4 + 0 +0+ 27	31
Initial Total		959
Duplicated and Retracted Papers		202
Total Papers include in Analysis		**756**

These records were exported in RIS format from Zotero and imported into VOSviewer for bibliometric and text-mining analysis. To ensure meaningful clustering and reduce noise, the minimum occurrence threshold for terms was set to 10, resulting in 277 terms that met the threshold. Based on VOSviewer's relevance scoring, the software retained 60% of the most relevant terms (n = 166) for visualization. The bibliometric map was generated using the "Association Strength" normalization method, with layout parameters adjusted to improve clarity and readability (Attraction = 7, Repulsion = 3). Clustering was performed using a resolution of 1.0 and a minimum cluster size of 4, with the option to merge small clusters enabled to reduce fragmentation. Visualization settings were further refined by adjusting label size, maximum term length, and link strength (minimum link strength = 4) to enhance readability. These steps collectively enabled the identification of the clusters, co-occurrence patterns, and research gaps within the literature related to MEP inspection and QA/QC practices in construction.

Results

Prior research related to MEP- VOSviewer Overlay (Year) Map

The VOSviewer “overlay visualization” shows different colors indicating the year of publication as shown in Figure 1 . In the figure, darker colors (blue) represent older topics that were more prevalent in earlier publications (around 2016–2017), while brighter colors (yellow) signify newer or more recently emerging topics (around 2019–2020). This color coding demonstrates the evolution of research themes in construction literature over time. Although the search encompassed publications from 2010 onward, the overlay visualization primarily highlights terms from 2016 to 2020. This is because earlier papers did not meet the minimum keyword occurrence, resulting in few or no repeatable terms contributing to the network. Conversely, publications after 2016 experienced rapid growth in research volume and employed more consistent, high-frequency keywords, leading these years to dominate the bibliometric map. Consequently, the overlay reflects the period when the development was most active and sufficiently indexed for inclusion in the visualization.

Figure 1. Year-Color Legend

General VOSviewer Overlay (Year) Map:

The general overlay visualization in Figure 2 shows widely studied issues within existing literature. Earlier studies (blue/teal) focus on topics such as “engineering,” “architecture,” “productivity,” “risk,” and “building information model”. More recent work (green/yellow) shifts toward analytical and computational approaches, with growing attention to terms like “analysis,” “implementation,” “algorithm,” and “MEP”. In more recent years, research activity (yellow) is concentrated around structural materials such as “concrete,” “strength,” and “compressive strength”, indicating that these topics have gained increasing attention between 2019 and 2020.

However, despite the broad coverage, the overlay visualization exposes a gap. Terms related to “slab,” “concrete slab,” or “in-slab MEP rough-ins” do not appear anywhere on the map, regardless of time period. While MEP and concrete appear as active and increasingly studied areas, their intersection in the context of pre-pour inspection or slab-embedded installation remains absent. This confirms that although both structural concrete and MEP systems have received growing attention individually, the literature continues to overlook the integration, placement accuracy, and inspection of MEP components within concrete slabs.

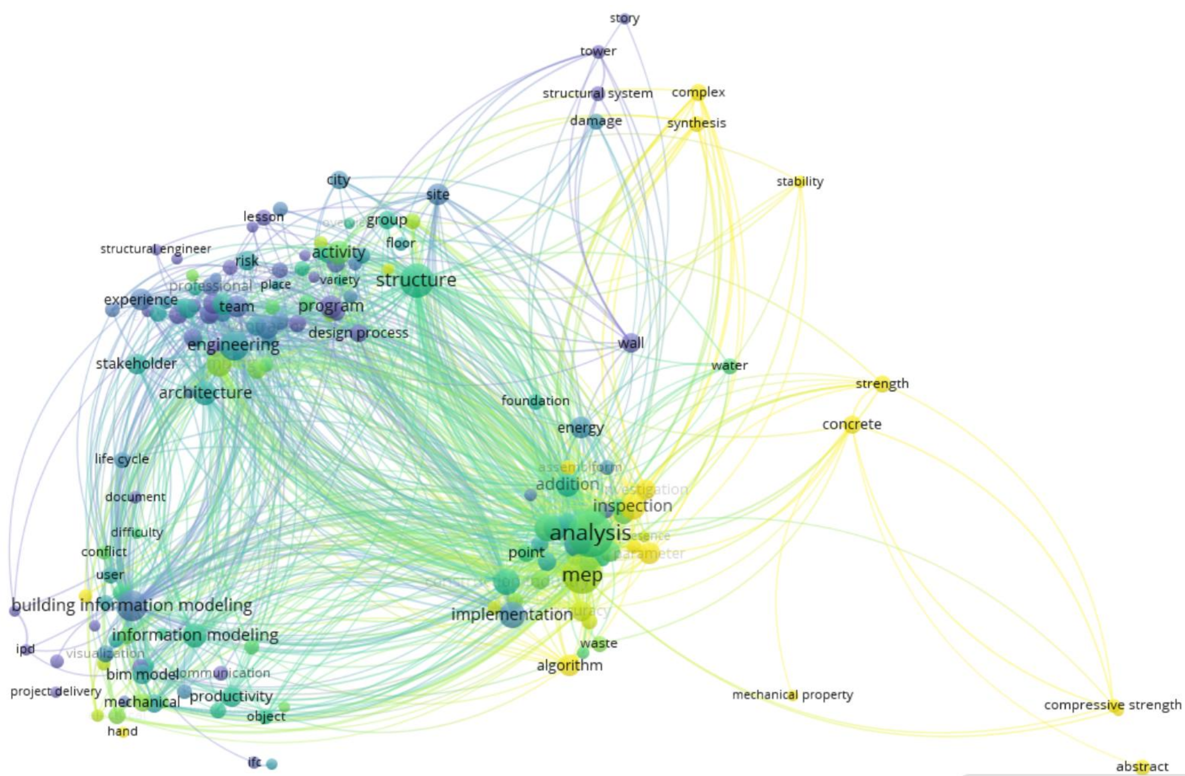

Figure 2. VOSviewer Overlay Map: General Trends

Prior research related to MEP - VOSviewer Network Map

The VOSviewer "Network visualization" shows the major clusters within the extracted literature for this study (See Table 2). Each node represents a frequently occurring term, and the size reflects the number of times it appears across the dataset, while the colored links show how often terms co-occur within the same publications. The map reveals four dominant clusters:

Table 2. Network Map-Key Clusters

Cluster Color	Focus Area	Key Terms
Red	BIM	Information modeling, project delivery, productivity, and engineering management.
Green	Analysis	Inspection, interaction, effects, responses, and conditions.
Yellow	Structure	Concrete, strength, mechanical properties, and stability.
Blue	Technique / Digital Methods / MEP Trades	Algorithms, accuracy, monitoring, experimental methods, productivity, plumbing, mechanical, electrical.

General VOSviewer Network Map:

The network visualization in Figure 3.Figure *2* shows that prior research related to MEP has primarily focused on the four main clusters mentioned above.
The red cluster centers on Building Information Modeling (BIM). It discusses areas such as clash detection, project delivery model, impact of BIM on productivity, efficiency, and decision-making, and stakeholder adoption challenges. Prior work here focuses on design-phase coordination and digital modeling, not on the installation or inspection of MEP embeds in concrete slabs.

This green cluster highlights analysis. It discusses areas that include inspection, interaction between different building systems, and studies examining responses, or effects. Prior work addresses general inspection and interaction, but not pre-pour verification of MEP rough-ins inside slabs.

This yellow cluster contains terms such as structure, concrete, strength, mechanical properties, and stability. This domain offers rich knowledge on concrete materials and structural performance but does not highlight any studies related to concrete slabs with MEP.

This blue cluster contains terms such as algorithm, accuracy, monitoring, experimental methods, plumbing, mechanical, electrical, and productivity. While digital methods for evaluating MEP accuracy exist, prior research has focused mostly on post-installation, not on real-time checks of MEP embeds before concrete placement.

The overall pattern across the clusters regarding previous work has been done on BIM modeling, Structure and concrete behavior, analysis, and techniques, as well as digital methods. But again, none of the clusters contained terms related to slab rough-in, MEP embedded items, or pre-pour inspection. This confirms that no existing research integrates MEP, concrete slab construction, and field-ready inspection tools.

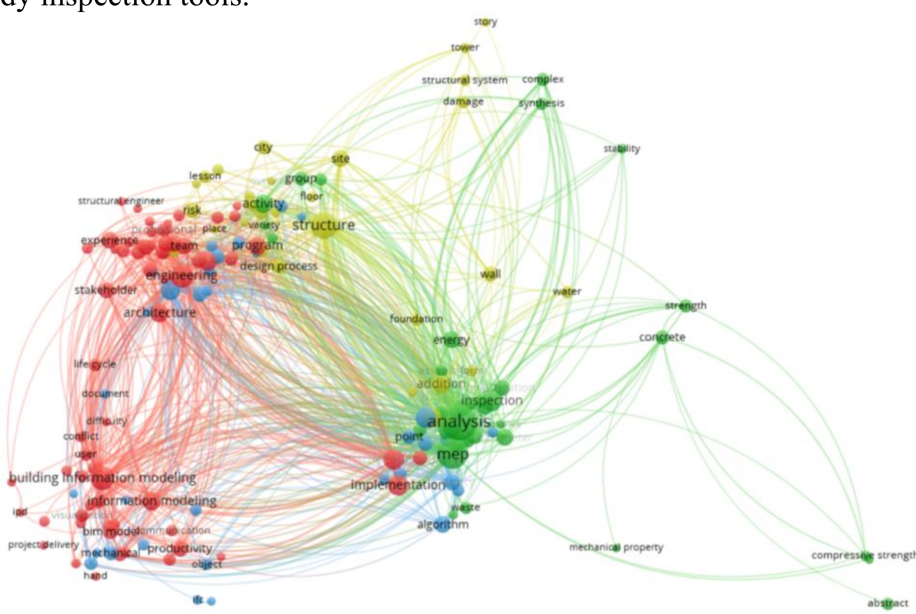

Figure 3. VOSviewer Network Map: General Clusters

MEP-Focused VOSviewer Network Map:

The network visualization in Figure 4Figure *2*. shows progress in research related to “MEP,” and the clusters connected to it. These clusters associated with the topic indicate that the literature has made progress in addressing issues related to MEP. It highlights discussions related to assessing construction waste and rework. BIM discussions (through digital modeling, data, productivity, clash detection). Stakeholder experience, perspective, and professional workflows. Concrete behavior (compressive strength, stability, damage, synthesis).

However, despite that previous literature clusters indicate that while the field has examined MEP from digital, analytical, and coordination perspectives, it has not yet addressed field installation or in-slab rough-in accuracy.

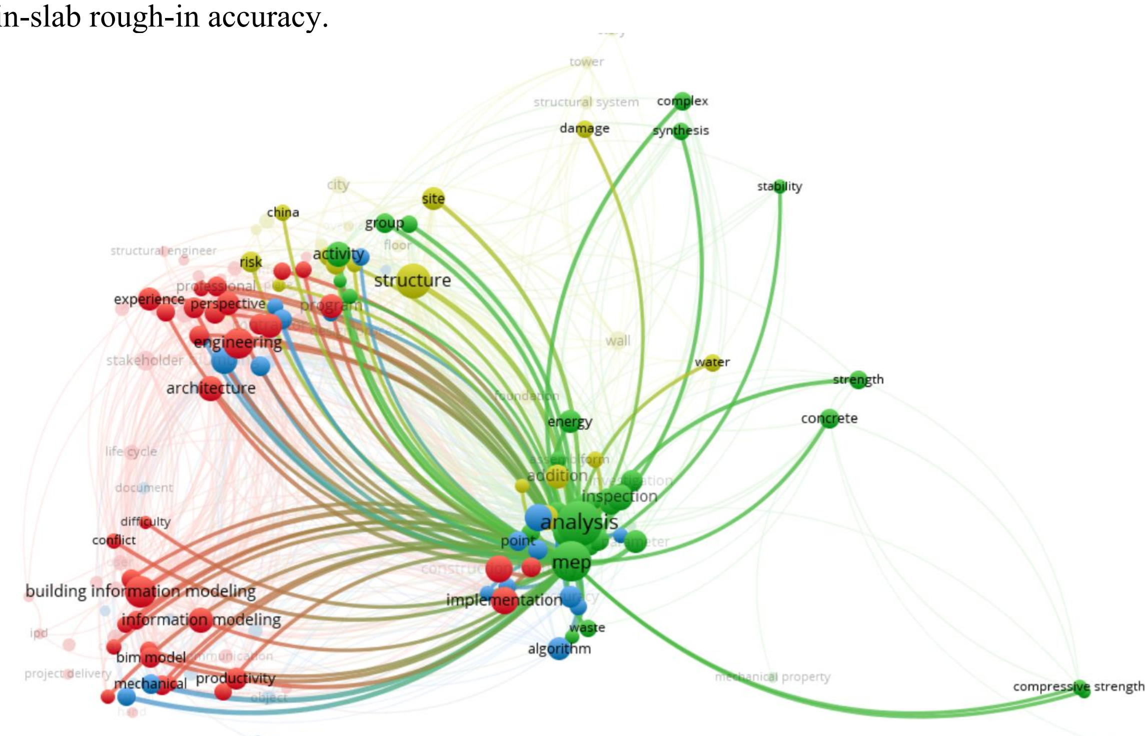

Figure 4. VOSviewer Network Map: MEP-Related Clusters

Concrete-Focused VOSviewer Network Map:

The network visualization in Figure 5Figure *2*. shows progress in research related to “concrete.” The links indicate that research does address the coordination of MEP systems with structural materials. However, the absence of the intersection between MEP, structure, and analysis indicates that models combining structural performance with MEP placement or embedment do not exist in the literature.

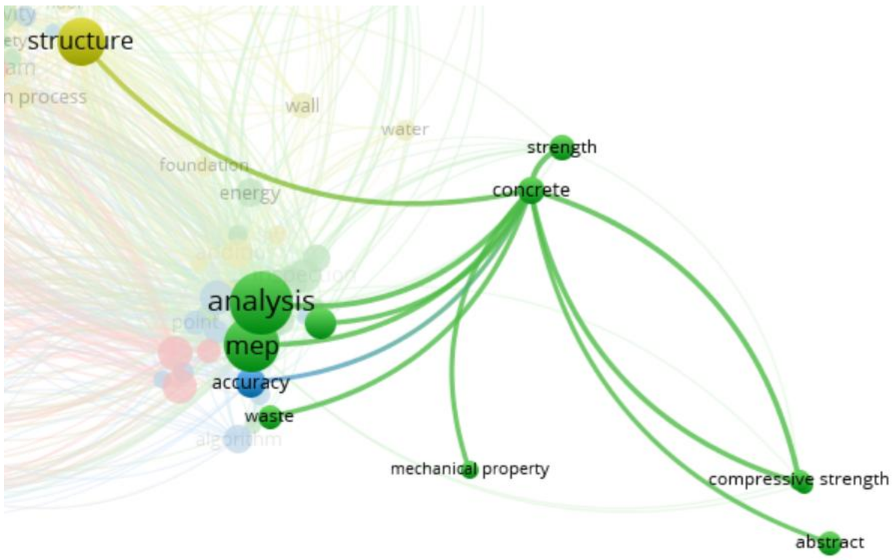

Figure 5. VOSviewer Network Map: Concrete-Related Clusters

Error-Focused VOSviewer Network Map:

In Figure 6. the focus shifts to “error”. Here, “error” links directly to MEP, algorithm, inspection, BIM, construction industry, analysis, and technique. This indicates that reducing errors has become a central theme in both the digital and organizational aspects of construction. Current research views error as an issue that relates to modeling accuracy, and analytical methods. However, it did not address the practical, field-level errors associated with the placement of MEP embeds in concrete slabs

Figure 6. VOSviewer Network Map: Error-Related Clusters

MEP disciplines Separately Focused VOSviewer Network Map:

The three visualizations in Figure 7. shows that the core MEP disciplines (plumbing, mechanical, and electrical) form the center of their respective subclusters. Each discipline links to terms such as accuracy, algorithm, and analysis, indicating that prior research has primarily examined MEP challenges through data processing. At the same time, all three MEP disciplines connect to Building Information Modeling (BIM), suggesting that existing studies frame MEP problems mainly within digital coordination, clash detection, and model-based workflows.

However, none of the MEP nodes connect to field-specific or construction-phase terms, such as, installation, embedded-item, and concrete slab. Furthermore, no prior research has addressed the errors and omissions that arise when these systems are physically embedded within concrete slabs. This study aims to fill that critical gap.

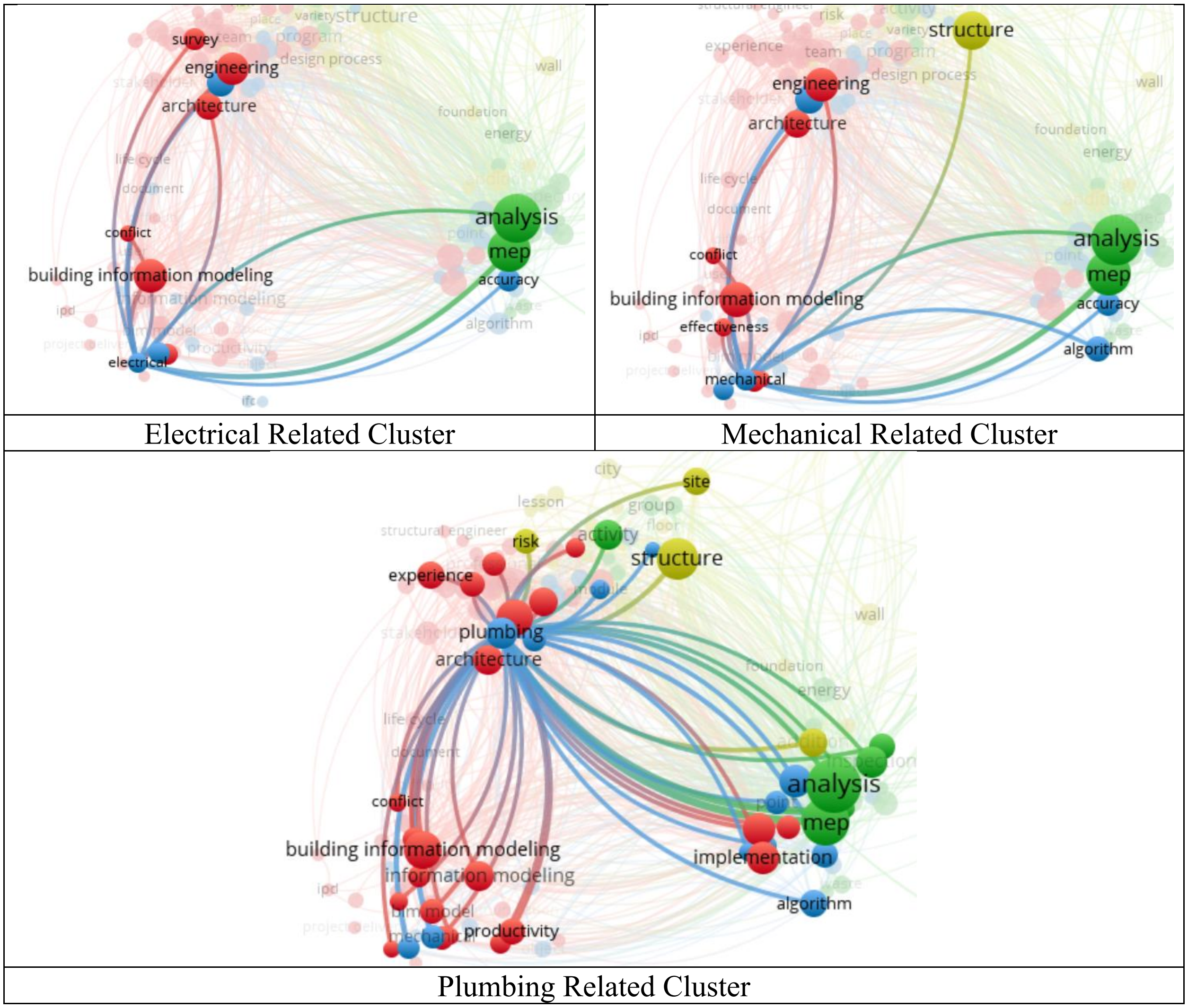

Figure 7. VOSviewer Network Map: Electrical/Mechanical/Plumbing -Related Clusters

Conclusions and Recommendations

The VOSviewer overlay (year) visualization gives us a look at how construction research has evolved over the past few years. Following this, the network visualization identifies four major clusters. Despite this diversity in topics, bibliometric analysis uncovers a critical research gap. While “MEP,” “analysis,” and “concrete” demonstrate strong connections, there are no references to “slabs, concrete slabs, embedded systems, or in-slab MEP rough-ins”. This absence is consistent across all clusters. Consequently, although research into MEP systems and concrete performance is active and growing, the specific integration and inspection of MEP components embedded within concrete slabs remain largely unexplored. This gap is particularly significant given the frequent occurrence of MEP-related field errors and omissions.

Importantly, this gap has direct implications for construction engineering and construction management education. Current curricula often emphasize BIM modeling, coordination theory, and structural design principles, but give a limited attention to pre-pour field verification of embedded MEP systems. The lack of research in this area indicates an educational gap in how future professionals are trained to identify and prevent E&O during the slab rough-in phase. By highlighting this overlooked intersection, the study informs curriculum development, training strategies, and experiential learning design within construction programs.

Future research and educational implementation should focus on developing physical mock-up models to experimentally assess MEP placement and E&O detection. Creating a controlled mock-up environment would enable researchers to systematically investigate the visibility, accessibility, and coordination challenges related to embedded MEP components. In addition, further research is needed to document the frequency, causes, and impacts of in-slab MEP E&O across different projects. Industry surveys and quantitative analyses would strengthen the understanding of this issue. Furthermore, incorporating augmented reality (AR) into these mock-up setups could create a practical platform for testing AR-assisted inspection procedures, evaluating the accuracy of E&O identification. Such studies would provide valuable insights into the feasibility and reliability of AR-supported inspection systems for enhancing the detection of errors and omissions in in-slab MEP installations.

Reference

[1] M. Fiaz and Y. Naiding, "Key Practices Circumscribing the Construction Complexities: Challenge for Chinese Construction Industry," *International Journal of Smart Home*, vol. 6, no. 4, 2012.

[2] A. Al-Janabi, M. Abdel-Monem, and K. El-dash, "Review study for rework causes in construction industry," ResearchGate. Accessed: Jul. 02, 2025. [Online]. Available: https://www.researchgate.net/publication/344480693_Review_study_for_rework_causes_in_construction_industry

[3] R. Asadi, S. Wilkinson, and J. O. B. Rotimi, "The common causes of rework in construction contracts: a diagnostic approach," *Journal of Engineering, Design and Technology*, vol. 21, no. 4, pp. 1107–1133, Aug. 2021, doi: 10.1108/JEDT-04-2021-0215.

[4] P. E. D. Love, "Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects," *Journal of Construction Engineering and Management*, vol. 128, no. 1, pp. 18–29, Feb. 2002, doi: 10.1061/(ASCE)0733-9364(2002)128:1(18).

[5] E. K. Simpeh, R. Ndihokubwayo, P. E. D. Love, and W. D. Thwala, "A rework probability model: a quantitative assessment of rework occurrence in construction projects," *International Journal of Construction Management*, vol. 15, no. 2, pp. 109–116, Apr. 2015, doi: 10.1080/15623599.2015.1033814.

[6] O. J. Olusegun and J. Guyimu, "Design Inadequacies and the Maintenance of University Buildings In Ilf-Ife, Nigeria," *SSRN Journal*, 2015, doi: 10.2139/ssrn.2784478.

[7] PRISMA, "Scoping," PRISMA statement. Accessed: Oct. 31, 2025. [Online]. Available: https://www.prisma-statement.org/scoping

[8] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," *Journal of Business Research*, vol. 133, pp. 285–296, Sep. 2021, doi: 10.1016/j.jbusres.2021.04.070.