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Common Errors and Omissions in Mechanical, Electrical, and Plumbing Systems Concrete Slabs Rough-In

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Mechanical, Electrical, and Plumbing (MEP) systems rough-in concrete slabs are crucial for the proper placement of MEP components across the building. The three most common rough-in components include a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves). However, the placement of these MEP rough-in components is prone to errors and omissions (E&O). The four most common issues associated with E&O are i- Dimensions, ii- Position, iii- Securing errors, and iv- Complete omissions. These issues can lead to delays, rework, and safety hazards. Unfortunately, there is limited research on quantifying the occurrence rate of this E&O. Thus, the problem that this research addresses is the lack of literature on E&O MEP rough-ins. Therefore, the objective of this paper is to identify and analyze the most frequent errors and omissions (E&O) that occur during MEP rough-in installation in concrete slabs. The methodology employed in this paper was quantitative, utilizing three descriptive analysis methods: (1) Frequency Distributions, (2) Relative Frequency Distribution, and (3) Weighted Numbers. The results indicate that dimension and positioning errors, particularly for components such as Embedded items (anchors or inserts) and trade-placed tubes (Sleeves), are consistently problematic.

Key Words: Errors and omissions, Construction delays, Efficiency, MEP

Introduction

The construction industry is known for its complexity, and it is common for errors and omissions (E&O) to occur, which can cause delays and increased costs. These E&O can also lead to negative consequences, including safety hazards and disputes between contracting parties (Sibanyama et al., 2012). Within this complex environment, E&O in the concrete slab rough-in for Mechanical, Electrical, and Plumbing (MEP) systems is particularly problematic, as it can cause significant problems in the overall construction of a building and may affect the integrity of the slab. The coordination of MEP design is a great challenge. Traditional reliance on 2D design tools often fails to capture spatial conflicts, resulting in errors that are not identified until construction. This late-stage detection creates delays, rework, and administrative burdens (Dantas Filho et al., 2016).

To improve the quality of construction, it is crucial to tackle the widespread issue of E&O. Preventing E&O in the placement or sizing of MEP systems rough-in concrete slabs is essential to avoid decreased operational efficiency, increased costs, and potential problems. Traditional construction practices, such as onsite observations, manual data collection and analysis, and human-driven decision-making, can be time-consuming and expensive (Yang et al., 2015), negatively impacting project schedules, budgets, and stakeholder profitability due to E&O. Using checklists and drawings during inspections enhances navigation between physical and mental processes, thereby reducing the likelihood of E&O (Al- Adhami, 2019). However, E&O persists. Therefore, it is essential to understand the challenges contributing to E&O in construction projects and effectively address and mitigate them to improve project outcomes.

The problem addressed by this research paper is E&O in concrete slab rough-in for MEP systems on construction sites. To address this problem, first, a systematic categorization of these MEP rough-ins is needed. Thus, the American Concrete Institute Guide to Formwork for Concrete (ACI-347) was used. According to the ACI-347, the three most common MEP rough-in components are: a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves) and the four most common issues with these components are i- Dimension, ii- Position, iii- Securing errors, and iv- Complete omissions. These E&O lead to problems such as delays, rework, and safety hazards (American Concrete Institute, 2004).

MEP Rough-in Components

The following are the definitions of each MEP Rough-in.

a. Embedded items include anchors or inserts:
   - Anchor: Anchors are fastening devices designed to hold or secure equipment, piping, or structural components to typically concrete.
   - Insert: anything other than reinforcing steel that is rigidly positioned within a concrete form for permanent embedment in the hardened concrete (American Concrete Institute, 2013).

b. Slab spaces created with forms including block-outs or bulkheads:
   - Bulkhead: a partition in formwork blocking fresh concrete from a section of the form, or a partition closing a section of the form, such as at a construction joint (American Concrete Institute, 2013).
   - Blockout: a space within a concrete structure under construction in which fresh concrete is not to be placed, called core in the United Kingdom (American Concrete Institute, 2013).

c. Trade place tubes, also known as sleeves:
   - Sleeve: (1) a pipe or tube passing through formwork for a wall or slab through which pipe, wires, or conduit can be passed after the forms have been stripped; (2) a device used around an anchor to accommodate adjustment and preloading of the anchor after the concrete has hardened (American Concrete Institute, 2013).

MEP Rough-in Common Issues

The following are the definitions of the four most common issues associated with the components mentioned above:

i. Dimensional errors: MEP rough-ins used on the job site do not match the sizes specified in the construction drawings.
ii. Positional errors: MEP rough-ins are incorrectly positioned or oriented on the job site in relation to the specified coordinates in the construction drawings.
iii. Securing errors: MEP rough-ins are not properly anchored, or fastened on the job site.
iv. Complete omissions: MEP rough-ins are completely omitted on the job site.

Therefore, the objective of this paper is to identify and analyze the most frequent errors and omissions (E&O) that occur during the MEP installation in concrete slabs of the three most common MEP rough-in components and the four most common issues.

Methodology

In this study, a quantitative descriptive research approach was employed. Quantitative methodology was utilized because it enabled a systematic investigation that included the collection and analysis of numerical data (Johnson & Christensen, 2020), and descriptive research was used because it allows for providing the variable characteristics without manipulating the variables (Cao et al., 2024).

The collection method used was an online survey, and the analysis method consisted of three commonly used methods. The survey was created using Qualtrics, comprising 21 questions: 16 closed-ended for quantitative analysis and 5 open-ended to gather additional insights. The target population consisted of construction professionals involved in the installation of MEP systems on concrete projects. Participants were selected using a judgmental/purposive non-random sampling method to align with the study's objectives (Etikan, 2017). The survey was presented at two Construction Career Fairs and one meeting of the National Association of Women in Construction. Industry professionals were approached, and 50 expressed interest in participating. The survey was emailed to 50 industry professionals, although not all participants completed it.

The three analysis methods used were: 1- Frequency Distribution, 2-Relative Frequency Distribution, and 3-Weighted Average, to prioritize E&O types by severity and frequency for resource allocation.

Method of Analysis 1 - Frequency Distributions: Frequency analysis refers to the number of times a specific data value occurs in your dataset (Frost, 2024; Lamba, 2021). A frequency distribution is a tabulation of the values that one or more variables take in a sample, which can be organized in a frequency table or illustrated graphically (Tsokos & Wooten, 2016). It offers a clear way to understand data distribution and concentration, visualized in tables. For instance, in construction, categorizing E&O by type can reveal patterns that indicate specific issues

Method of Analysis 2 - Relative Frequency Distribution: A relative frequency is a measure between 0 and 1 that describes the frequency with which the values of the variable take relative to the sample size, n (Tsokos & Wooten, 2016). Relative frequencies do not use raw counts. Instead, they relate the count for a particular type of event to the total number of events using percentages, proportions, or fractions (Frost, 2021). This method helps in understanding the weight of each category within the whole dataset, such as understanding the E&O in construction projects.

Method of Analysis 3 – Weighted Value: Weighted Value is a way to adjust the varying frequencies within a dataset, providing a balanced measure that reflects the relative impact of each value (Ganti et al., 2024). Weighted scoring is a method of prioritizing projects by assigning a numeric value to each task according to the cost-benefit (or effort-to-value) analysis. Provides a total that reflects the E&O for each value.

Results and Analysis

The survey data were analyzed using the three methods described above, with the help of Excel, to provide insights into the prevalence of E&O in concrete slab rough-ins for MEP systems. The analyses helped identify the primary factors contributing to these E&O, enabling targeted interventions to improve accuracy and reduce future occurrences.

Demographic Information

Of the 50 professionals who received the survey, a total of 23 responded to it, providing valuable insights. Although not all professionals answered every question, 23 responses were received for the "Company Type" question, providing a comprehensive overview. Those responses indicated that 47.8% of the participants were general contractors, 21.7% were subcontractors/specialty contractors, 13.0% were engineering firms, 13.0% were design firms, and 4.3% were owner/owner representatives. The results indicate a diverse mix of participants from various sectors of the construction industry.

Descriptive Approaches for Analyzing the Data

This study analyzes three key MEP rough-in components: a) embedded items (anchors or inserts), b) slab space created with formwork (block-outs or bulkheads), and c) trade-placed tubes (sleeves). It also examines four common issues: i) dimensions, ii) position, iii) securing errors, and iv) complete omissions. The participants were asked the question: “During the formwork construction for concrete slabs, how often does each of the E&O listed impact your projects (Approximately)?”. There were 17 responses to this question. The different analyses of the responses are summarized in the sub-sections. Tables 1 through 4 are organized, with the three common MEP rough-in components listed vertically (a, b, c) and subdivided into the four common issues (i, ii, iii, & iv). The different percentages of projects impacted by E&O are listed horizontally (0%, 1% to 5%, 6% to 19%, 20% to 39%, 40% to 59%, 60% to 79%, and 80% to 99%). The first option of 0% was included to allow participants to be able to indicate that their companies did not have this type of E&O. Then, the first interval of 1 to 5% was included to allow participants to indicate a small percentage of occurrence of E&O. the, second interval of 6% to 19% was included to get to the next regular interval of 20% each.

Method of Analysis 1 - Frequency Distributions: The frequency distribution analysis of E&O is presented in Table 1. The “Frequency" row represents the cumulative number of responses per item/issue that falls within each of the specified percentages of projects impacted. The highest cumulative frequency is 100, recorded in the “1% to 5% of projects impacted” category, suggesting that E&O related to MEP rough-in predominantly affects 1% to 5% of projects within the respondents’ companies. The second highest cumulative frequency, 46, falls within the “6% to 19% of projects impacted,” indicating that these errors secondarily impact between 6% and 19% of projects. Additionally, the third highest frequency of 28 corresponds to the “40% to 59% of projects” category. It is worth noting that out of the total of 204 frequencies, only 7 responses indicated that 0% of the projects were impacted by this type of E&O, revealing that most projects suffer from MEP rough-ins E&O.

Table 1 also reveals that the majority of the participants reported experiencing ‘dimension of slab space created with form (block-outs or bulkheads) (b.i)’, with 11 reports. Similarly, the ‘dimension of embedded items (anchors or inserts) (a.i)’, and ‘complete omissions of slab space created with form (block-outs or bulkheads (b.iv)’; each had 10 reports. Additionally, ‘complete omissions of trade place tube (sleeves) (c.iv)’, ‘position errors of slab space created with form (block-outs or bulkheads) (b.ii)’, and ‘complete omissions of embedded items (anchors or inserts) (a.iv)’ were noted 9 times. These findings suggest that complete omissions and dimensional errors are common issues, underscoring the need for better oversight and attention to detail in construction to minimize such errors and omissions (E&O).

Table 1. Analysis Method 1: Frequency distributions

Common rough-in components & issues	Percentage of Projects Impacted by E&O						
	0%	1% to 5%	6% to 19%	20% to 39%	40% to 59%	60% to 79%	80 % to 99%
a.i	0.0	10.0	3.0	1.0	3.0	0.0	0.0
a.ii	0.0	8.0	4.0	1.0	2.0	1.0	1.0
a.iii	0.0	7.0	5.0	1.0	3.0	0.0	1.0
a.iv	1.0	9.0	4.0	1.0	1.0	0.0	1.0
b.i	0.0	11.0	2.0	1.0	3.0	0.0	0.0
b.ii	0.0	9.0	3.0	2.0	3.0	0.0	0.0
b.iii	0.0	9.0	4.0	2.0	2.0	0.0	0.0
b.iv	0.0	10.0	4.0	2.0	1.0	0.0	0.0
c.i	2.0	7.0	2.0	3.0	2.0	1.0	0.0
c.ii	2.0	6.0	4.0	1.0	3.0	1.0	0.0
c.iii	1.0	5.0	5.0	1.0	4.0	1.0	0.0
c.iv	1.0	9.0	6.0	0.0	1.0	0.0	0.0
Total Frequency	7	100	46	16	28	4	3

Legend: a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place-tube (Sleeves).
i- Dimension errors, ii- Position errors, iii- Securing errors, and iv- Complete omissions.

Method of Analysis 2 - Relative Frequency Distribution (RFD): The relative frequency distribution (RFD) analysis was implemented twice. First to focus on the project impacted and second to focus on common errors and omissions. The findings are shown in Table 2 and Table 3.

2a.- Relative Frequency Distribution (RFD) of Project Impact: This first relative frequency distribution analysis used the total frequency for each percentage of projects impacted, shown in Table 1. Therefore, all columns in Table 2 total 100%, and the responses are normalized according to the percentage of projects impacted (Columns). The "Total RFD 1 " provides a cumulative count of affected projects for each rough-in component and issue. While “Normalized RFD 1” provides the normalized by count of responses. In " NRFD 1", the highest cumulative percentage is 15% for position errors of embedded items (anchors or inserts) (a.ii). This indicates that this is the most common E&O when normalizing by the percentage of projects impacted. The second most reported cumulative percentage was 11% for securing errors of embedded items (anchors or inserts) (a.ii), and the third most reported cumulative percentage was 10% for dimension errors of trade-place tubes (sleeves) (c.i). These percentages indicate that many of the projects encountered issues with trade-placed tubes or sleeves, whether due to dimensional discrepancies or positioning errors.

When analyzing Table 2, the percentage of projects impacted. It can be seen that "1% to 5% of projects" experienced mainly dimension errors in slab space created with form (block-outs or bulkheads (b.i), with 11% of projects reporting this specific issue. Additionally, “6% to 19% of projects" experienced mainly complete omissions of trade-place tubes (sleeves) (c.iv), with 13% of projects reporting this specific issue. Furthermore, "20% to 39% of projects" experienced mainly dimension errors in trade-place tubes (sleeves) (c.i), with 19% of projects reporting this specific issue. Moreover, "40% to 59% of projects" experienced mainly the following issues; dimension errors in embedded items (anchors or inserts) (a.i), and securing errors in embedded items (anchors or inserts) (a.iii), and dimension errors in slab space created with form (block-outs or bulkheads (b.i), position errors in slab space created with form (block-outs or bulkheads (b.ii), and position errors in trade place tube (sleeves) (c.ii), with each 11% of projects reporting these specific issues. Also, "60% to79% of projects" experienced mainly (a.i), dimension errors in trade place tube (sleeves) (c.i), position errors in trade place tube (sleeves) (c.ii), securing errors in trade place tube (sleeves) (c.iii). Finally, "80% to 99% of projects" experienced mainly position errors of embedded items (anchors or inserts) (a.ii), securing errors of embedded items (anchors or inserts) (a.iii), and complete omissions of slab space created with form (block-outs or bulkheads (b.iv), with 33% of projects reported these specific issues.

Table 2. Analysis Method 2a: Relative Frequency Percentage by Percentage of Projects Impacted

Common rough-in component & issues	Percentage of Projects Impacted by E&O								
	0%	**1% to 5%**	**6% to 19%**	**20% to 39%**	**40% to 59%**	**60% to 79%**	**80 % to 99%**	**Total RFD 1**	**NRFD 1**
a.i	0%	10%	7%	6%	11%	0%	0%	33%	6%
a.ii	0%	8%	9%	6%	7%	25%	33%	88%	15%
a.iii	0%	7%	11%	6%	11%	0%	33%	68%	11%
a.iv	14%	9%	9%	6%	4%	0%	33%	61%	10%
b.i	0%	11%	4%	6%	11%	0%	0%	32%	5%
b.ii	0%	9%	7%	13%	11%	0%	0%	39%	6%
b.iii	0%	9%	9%	13%	7%	0%	0%	37%	6%
b.iv	0%	10%	9%	13%	4%	0%	0%	35%	6%
c.i	29%	7%	4%	19%	7%	25%	0%	62%	10%
c.ii	29%	6%	9%	6%	11%	25%	0%	57%	9%
c.iii	14%	5%	11%	6%	14%	25%	0%	61%	10%
c.iv	14%	9%	13%	0%	4%	0%	0%	26%	4%

Legend: a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade-place tube (Sleeves).
i- Dimension errors, ii- Position errors, iii- Securing errors, and iv- Complete omissions.

2b.- Relative Frequency Distribution (RFD) of Common E&O components and issues: This second relative frequency distribution analysis used the total frequency for each common rough- in component and issues (that are shown in Table 1). Therefore, all rows in Table 3 total 100%, and the responses are normalized according to the components and issues (Rows). The "Total RFD 2" provides a cumulative count across all common rough-in components per percentage of projects. While “Normalized RFD 2” is normalized by the count of responses. In "NRFD 2", the highest cumulative percentage is 49%, indicating that E&O affects most responses between “1% and 5% of the projects”. The second most reported cumulative percentage was 23%, indicating that E&O still affects a notable portion of projects with “6% to 19% of the projects”, and the third most reported cumulative percentage was 14%, corresponding to “40% to 59% of the projects” highlighting areas where more rigorous quality control could be beneficial to reduce these higher-impact occurrences.

When analyzing the Table 3 percentage. It can be seen that 59% of the responses have 1% to 5% of their projects impacted by MEP rough-ins due to dimension errors of embedded items (anchors or inserts) (a.i). Additionally, 35% of the responses have 6% to 19% of their projects impacted by MEP rough-ins due to complete omissions of trade place tubes (sleeves) (c.iv)’. Furthermore, 18% of the responses indicate that MEP rough-ins impact 20% to 39% of their projects due to dimension errors in trade-place tube (sleeves) (c.i). Moreover, 24% of the responses have 40% to 59% of their projects impacted by MEP rough-ins due to securing errors in trade place tubes (sleeves) (c.iii). Also, 6% of the responses have 60% to 79% of their projects impacted by MEP rough-ins due to dimension errors in trade-place tube (sleeves) (c.i), position errors in trade-place tube (sleeves) (c.ii), securing errors in trade place tube (sleeves) (c.iii). Finally, 6% of the responses have 80% to 99% of their projects impacted by MEP rough-ins due to positioning errors in embedded items (anchors or inserts) (a.ii), and securing errors in embedded items (anchors or inserts) (a.iii), complete omissions of embedded items (anchors or inserts) (a.iv).

Table 3. Analysis Method 2b: Relative Frequency Distribution by Common Rough-in

Common rough-in components & issues	**Percentage of Projects Impacted by E&O**						
	0%	**1% to 5%**	**6% to 19%**	**20% to 39%**	**40% to 59%**	**60% to 79%**	**80% to 99%**
a.i	0%	59%	18%	6%	18%	0%	0%
a.ii	0%	47%	24%	6%	12%	6%	6%
a.iii	0%	41%	29%	6%	18%	0%	6%
a.iv	6%	53%	24%	6%	6%	0%	6%
b.i	0%	65%	12%	6%	18%	0%	0%
b.ii	0%	53%	18%	12%	18%	0%	0%
b.iii	0%	53%	24%	12%	12%	0%	0%
b.iv	0%	59%	24%	12%	6%	0%	0%
c.i	12%	41%	12%	18%	12%	6%	0%
c.ii	12%	35%	24%	6%	18%	6%	0%
c.iii	6%	29%	29%	6%	24%	6%	0%
c.iv	6%	53%	35%	0%	6%	0%	0%
Total RFD 2	41%	588%	271%	94%	165%	24%	18%
Normalized RFD 2	3%	49%	23%	8%	14%	2%	1%

Legend: a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade-place tube (Sleeves).
i- Dimension errors, ii- Position errors, iii- Securing errors, and iv- Complete omissions.

Analysis methods 2a and 2b are similar, but each approach highlights different aspects of the data. Method 2a focuses on the distribution of errors within the percentage of projects impacted by E&O to understand which errors are more common across various percentages of projects, while method 2b emphasizes the frequency of errors by impact level to understand how often different impact levels occur across.

Method of Analysis 3- Weighted Value: Weighted Value analysis of E&O is presented in Table 4. It is organized vertically according to the three MEP common rough-in components E&O subdivided into the four common issues. It is organized horizontally into the weighted values for each percentage of projects impacted by each E&O. Providing a detailed view of how errors are distributed across different levels of project impact.

"Total Weighted Value 1" highlights which project ranges are most affected by E&O, making it useful for targeting high-impact project phases or categories. The highest cumulative impact value is 13.87, indicating that E&O affects “0% to 19% of the projects” the most. The second most reported cumulative impact value was 13.86, indicating that E&O has a substantial impact on projects within the "40% to 59% of the projects”. "Total Weighted Value 2" shows which specific E&O types contribute the most to the cumulative impact across all projects, making it useful for prioritizing corrective actions on critical error types. The highest cumulative value is 3.92, indicating that Securing errors of the Trade-place tube (Sleeves) are the most likely to occur. The second most common occurrence is that the cumulative value was 3.43, indicating that dimension and position errors of the Trade-place tube (Sleeves) affect projects. When analyzing Table 4 weighted average. 1.43 complete omissions of trade place tubes (sleeves) (c.iv) are impacted in projects weighted at 9.5. Additionally, 0.89 dimension errors in trade place tube (sleeves) (c.i) are impacted in projects weighted at 29.5. Furthermore, 1.98 securing errors of trade place tube (sleeves) (c.iii) are impacted in projects weighted at 49.5

Table 4. Analysis Method 3: Weighted Average

Common rough-in components & issues	Weighted Value of Projects Impacted by E&O					
	9.5%	29.5%	49.5%	69.5%	89.5%	Total Weighted Value 2
a.i	1.24	0.30	1.49	0.00	0.00	3.02
a.ii	1.14	0.30	0.99	0.70	0.90	3.12
a.iii	1.14	0.30	1.49	0.00	0.90	2.92
a.iv	1.24	0.30	0.50	0.00	0.90	2.03
b.i	1.24	0.30	1.49	0.00	0.00	3.02
b.ii	1.14	0.59	1.49	0.00	0.00	3.22
b.iii	1.24	0.59	0.99	0.00	0.00	2.82
b.iv	1.33	0.59	0.50	0.00	0.00	2.42
c.i	0.86	0.89	0.99	0.70	0.00	3.43
c.ii	0.95	0.30	1.49	0.70	0.00	3.43
c.iii	0.95	0.30	1.98	0.70	0.00	3.92
c.iv	1.43	0.00	0.50	0.00	0.00	1.92
Total Weighted Value 1	13.87	4.72	13.86	2.78	2.69	

Legend: a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade-place tube (Sleeves).
i. Dimension errors, ii- Position errors, iii- Securing errors, and iv- Complete omissions.

Conclusions and Practical Implications

This study aimed to provide insights into the frequency of E&O incidents during MEP rough-in installation in concrete slabs. Three analysis methods were used to create a robust understanding of MEP rough-in E&O:

- *Dimensioning errors related to slab spaces (e.g., block-outs or bulkheads)*: the frequency distribution analysis (Method 1) revealed that most respondents reported experiencing this type of E&O in 1% to 5% of their projects. Although the overall occurrence rate may appear low, the cumulative impact of these errors across multiple projects is significant.
- *Position errors, securing errors, and complete omission of embedded items (e.g., anchors or inserts):* The relative frequency distribution (Method 2A highlighted the variability in E&O types across different project impact percentages.
- *Dimensioning errors related to slab space (e.g., block-outs or bulkheads)*: The relative frequency distribution (Method 2B) revealed that most reported this type of E&O in 1% to 5% of them. projects
- *Securing errors for trade-placed tubes:* The weighted value approach demonstrates that this type of E&O is the most prevalent when accounting for impacts on project performance.

The practical implications of revealing that those are the three most prevalent MEP rough-in E&O are that:

- *Focused Supervision and Quality Control Procedures:* enable the superintendent to implement quality control procedures that focus on the most common occurrences of E&O, thereby reducing their negative impact on project timelines, quality standards, and resource allocation, and ultimately mitigating rework that delays progress and increases costs. It has been determined that a major cause of rework is poor management (Ye et al., 2015)
- *Specific Training:* Focusing on the E&O identified in this study could mitigate E&O because studies have shown that the primary cause of E&O in construction projects is substandard workmanship (Janipha & Ismail, 2013; Sin et al., 2024).
- *Completed Work Protection:* Protecting completed work is often overlooked due to perceived administrative burdens, resulting in rework and inefficiencies. However, safeguarding finished components prevents damage, reduces E&O, and improves project delivery. Because studies have found that strong planning and a commitment to quality management are crucial to addressing E&O (Irani & Edwards, 2004).
- *Documented MEP rough-in E&O:* Documented MEP rough-in E&O establishes a baseline for identifying patterns and implementing corrective measures.
- *Focus on Technology Implementation*: Leveraging technologies like augmented reality (AR) can help address these challenges by enhancing accuracy and efficiency. Future research should focus on integrating these tools into methodologies to evaluate their effectiveness. Because inadequate technology has been identified as a cause of rework due to E&O (Ye et al., 2015).

Limitations and Future Work

Although this study provides valuable insights, it has limitations and areas for future work that are necessary to effectively generalize the results. The following are some of the future work recommendations:

- *Expand Sample Size:* Increasing the number of participants and including a broader range of roles in the research would offer a wider diversity of perspectives and a stronger basis for evaluating statistical significance.
- *Direct E&O on Site:* Changing the data collection process from surveys of industry professionals to direct measurements of E&O on construction sites would provide a more accurate representation of the industry situation.
- *Cost and Time Impact:* Quantifying the cost and schedule impacts associated with E&O would help identify potential opportunities for budget and schedule improvements should the E&O be reduced.
- *E&O Workbench:* Developing a mock-up project document with common MEP Rough-in components and building a physical model with E&O purposely placed would provide an opportunity to test procedures and technologies that could be implemented to mitigate E&O.
- *Technology Implementation:* Conducting case studies that compare visual inspections without the use of technology against inspections that implement technologies (such as mobile devices, augmented reality, and time capture tools) would evaluate the impact of technology in reducing E&O.

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