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Virtual Design and Construction (VDC) Time Study: Creating National Benchmarking Metrics for the MEP Trades

JRGF John R. Gentille Foundation

NEW HORIZONS FOUNDATION A Chance to Grow

ELECTRI INTERNATIONAL Research and Education for the Electrical Construction Industry

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Executive Summary

The construction industry's increasing reliance on Virtual Design and Construction (VDC) has created a growing need for standardized benchmarking metrics to evaluate performance, allocate resources, and inform strategic planning. While developing national benchmarking metrics is a promising goal, achieving it will require ongoing collaboration across the industry. This report presents the results of a foundational study for the Mechanical, Electrical, and Plumbing trades (MEP). A team from the University of Washington led the effort, in partnership with Electri International, John R. Gentille Foundation, New Horizons Foundation, and over 25 companies, to explore current VDC practices and propose a path forward.

We present the findings in four sections. The VDC Task Schema development, task-role-responsibility mapping, assessment of the levels of automation in fabrication processes, and the tools to support the creation of company-level and industry-level metrics. We present the findings in each section and discuss the industry implications and practical recommendations. First, in the VDC Task Schema Development, the team defined four categories of work in VDC departments for the MEP trades: 1) Modeling and Shop drawing creation, 2) Internal management and coordination, 3) external management and coordination, and 4) Fabrication Support. See Appendix A for the complete schema.

VDC Task Schema: Industry Implications

- **Standardization**: The VDC Task Schema provides a consistent framework to define and categorize tasks, reducing ambiguity and improving communication across the industry.
- **Time Tracking**: Aligning internal practices with the schema enables more precise time tracking, helping organizations analyze resource use and optimize workflows across the four categories of work. Many of the companies in our study focus on modeling tasks, and using this schema would also allow for analysis of management and fabrication support tasks.
- **Benchmarking**: A shared schema allows for meaningful comparisons, supporting benchmarking and the identification of best practices both within and between companies. The tools provided in section four will enable the industry to aggregate data across the industry to create national metrics.

VDC Task Schema: Practical Recommendations

- **Integrate into Tools**: Companies should incorporate the VDC Task Schema into time-tracking and project management systems for consistent measurement and performance improvement.

- **Training and Onboarding**: Companies can use the schema as a foundation for training and onboarding to ensure consistent understanding of tasks, the clarification of responsibilities, and accurate application across teams.
- **Collaboration and Benchmarking**: We encourage industry-wide adoption of the schema to support cross-company benchmarking, knowledge sharing, and best practice development.
- **Ongoing Refinement**: We recommend continuous refinement and expansion of the schema based on real-world feedback and document changes to support transparency and future improvements.

Second, in the Task-Role-Responsibility Mapping section, this report summarizes the analysis of three VDC roles: detailer, coordinator, and manager. We surveyed attendees of the 2025 MEP Innovation Conference (Los Angeles, January 2025) to explore how consistent the industry is in defining the responsibilities across these three roles. While there is some consistency across some of the task categories (such as modeling and shop drawing creation), high variability exists across many tasks, suggesting that roles and responsibilities vary across the industry.

- **Relationship between Roles:** The detailer and manager roles relate to each other, while the coordinator takes on a more independent role in terms of responsibilities across most task categories.
- **Responsibility Patterns of Roles:** The roles of coordinator, detailer, and manager show high levels of consistent responsibility patterns across the industry for specific task categories, particularly in category 1: Modeling and Shop Drawing creation, with some variability in task categories like ‘Internal Management and Coordination’ and ‘Fabrication Support’.
- **Detailer Responsibilities Pattern:** The detailer consistently performs ‘Modeling & Shop Drawing Creation’ tasks, but shows the highest variability in responsibilities for ‘Internal Management and Coordination’ and ‘Fabrication Support’ with a mix of perform, consulted, oversee, and not applicable.
- **Manager Responsibilities Pattern:** The manager mainly performs and oversees tasks. They predominantly oversee ‘Modeling & Shop Drawing Creation’ tasks, and perform ‘Internal Management and Coordination’, while they show a mix of perform and oversee ‘External Coordination’ and ‘Fabrication Support’ tasks.
- **Coordinator Responsibilities Pattern:** The coordinator often functions as a connector across teams, especially in inter-organizational settings. While frequently performing or being consulted in coordination tasks, the role shows limited involvement in ‘Fabrication Support’.

- **Roles-Responsibilities versus Trades:** The individual MEP trades follow similar Task-Role-Responsibility mapping as shown in Figure 3-1, with supporting details in Figures B-2 to B-5 (Appendix B). Some variability exists, where certain trades show stronger or weaker patterns for specific task categories.

- **Impact of Experience:** Years of experience impact the survey results of job roles and team dynamics (Figures B-6 to B-9, Appendix B), indicating variation in the understanding of shared working practices across the project teams.

- **VDC Department vs Executive Management:** The VDC department and executive management show overall alignment in Task-Role-Responsibility perceptions (Figures B-10 to B-13, Appendix B). However, some mismatches exist in understanding specific responsibilities, which may influence project performance.

Task-Role-Responsibility Mapping: Industry Implications

- **Industry Fragmentation:** There is ambiguity and variability in roles and responsibilities for the VDC tasks. This fragmentation leads to challenges for the management of projects and workforce planning.

- **Resource Misallocation:** The ambiguity related to Task-Role-Responsibility could lead to misallocation of resources and over or under allocating tasks that undermine the team's performance.

- **Time Misallocation:** There is misallocation of time being spent for the VDC tasks due to absence of different types of responsibility. Tasks-Role-Responsibility mapping clarifies responsibility types, supporting time estimation and resource planning. However, varying roles and responsibilities across organizations challenge project managers to align team expectations.

- **Ambiguity and Career Progression:** Misallocation of time and resources also hinders clarity in job responsibilities, communication and collaboration. This ambiguity leads to inaccurate expectation and accountability, that undermines career development within teams and across the MEP industry.

- **Industry-Wide Benchmarking Metrics:** The variability in understanding of Task-Role-Responsibility, misallocation of resources and time are the barriers to develop industry-wide benchmarking metrics. A consistent benchmarking metrics would support performance comparisons, encourage best practice sharing, and drive overall industry improvement.

- **Industry-Wide Advancement:** Lack of structured Task-Role-Responsibility mapping hinder the MEP industry to address fragmented role-responsibility definitions and improve task alignment. A consistent Task-Role-Responsibility mapping would support precise project execution, better team coordination, and progress toward standardized industry benchmarking.

Task-Role-Responsibility Mapping: Practical Recommendations

- **Optimize Resource Allocation:** We recommend that companies adopt the Tasks-Roles-Responsibilities mapping
- to redefine task, resource, and time allocation by recognizing different responsibility types, leading to clearer expectations and improved management of VDC tasks in the MEP industry.
- **Foster Team Adoption:** We recommend that companies implement Tasks-Roles-Responsibility mapping as a team in the VDC department to improve workflow, communication, and collaboration.
- **Clarify Role for Growth:** We recommend companies use Task-Role-Responsibility to set expectations for job roles and career progression that will attract talent to the MEP industry.
- **Customize per Trade:** We recommend refining and adjusting Task-Role-Responsibility mapping to a particular trade to support industry-wide national benchmarking for MEP trades.

Third, the report addresses an assessment of the levels of automation in Fabrication Processes. We sought to understand the state of the practice and how differences across the industry may impact VDC activity task metrics.

- **Task Automation:** Subcontractors automate fabrication support tasks by streamlining drawing production, documentation, and bill of materials preparation. They use in-house tool palettes, address interoperability issues between software packages, and make decisions about using off-the-shelf products or developing software in-house. These efforts are embedded within model-based workflows beyond 3D coordination and shop drawing creation.
- **Drawing and Documentation Typologies:** All respondents consistently use various drawing types, such as shop drawings, fabrication drawings, spool sheets, material lists, and as-built drawings. While shop and as-built drawings are typically required contractually, subcontractors use fabrication drawings, spool sheets, and material lists internally to support fabrication, procurement, and field installation.

Levels of Automation: Industry Implications

Companies across the MEP industry operate at different levels of automation, with electrical firms on the lower end. Companies achieve higher levels of automation through automating repetitive tasks, configuring interoperability, and model-based workflows. This spectrum of automation levels might influence Task-Role-Responsibility mapping and time allocation, thus resulting in variability in the MEP industry.

Levels of Automation: Practical Recommendations

Multiple opportunities exist to improve VDC performance in the MEP industry through technology and process upgrades. Companies are using customized off-the-shelf/in-house tools, and model-based workflows to enhance information detail, reduce redundancy, and integrate systems—an attempt toward holistic improvement supported by Task-Role-Responsibility mapping. Companies we interviewed continue to explore opportunities to automate and create more efficient processes.

The fourth section introduces the tools for creating National Benchmarking Metrics. The team created two tools to support the creation of metrics. Companies can use these tools to analyze their own data or aggregate data from multiple companies for cross-industry metrics. The first tool allows companies to transform their proprietary and customized task time tracking data to a standard, sharable format. The second tool allows users to see the metrics based on trade, vertical market, new or retrofit project type, and VDC role. Users can filter these metrics based on the tasks they select to see the distribution of time spent on these tasks.

Tools for Creating National Benchmarking Metrics: Industry Implications

- **Operational Insight**: The tools provide a structured way to visualize how VDC teams allocate time, helping identify high-effort tasks and guide decision-making.
- **Flexibility & Inclusiveness**: Customizable task selection makes the metrics adaptable to different company structures and project scopes.
- **Benchmarking Foundation**: Standardized time data allows for meaningful internal evaluations and cross-company comparisons to inform best practices.

Tools for Creating National Benchmarking Metrics: Practical Recommendations

- **Create Company Benchmark**: We recommend that companies use historical project data to set performance baselines, track improvements, and guide long-term strategy.

- **Benchmark Ongoing Projects**: We recommend that companies apply metrics in real-time to detect performance gaps early and support proactive project management.
- **Industry-wide Benchmarking System**: We recommend that the industry associations promote secure, anonymized data-sharing under a trusted framework to enable large-scale benchmarking and collaborative growth.

Introduction

The construction industry is experiencing a shift toward digitalization, driven by rapid technological advancements and the growing demand for improved efficiency, coordination, and project outcomes. One of the most widely adopted approaches in this transformation is Virtual Design and Construction (VDC). Rather than being as a standalone technology, VDC is a process-oriented methodology that brings together multi-disciplinary models, construction planning, and collaborative workflows to support informed decision-making. By enabling teams to simulate construction activities in a virtual environment before physical work begins, VDC helps minimize design conflicts, improve coordination among stakeholders, and optimize project sequencing. As projects become increasingly complex and involve many stakeholders, VDC continues to evolve as a practical solution.

Despite its growing adoption, a critical challenge emerges: the construction industry lacks a standardized, data-driven framework for evaluating the effectiveness of VDC practices across diverse project types and market sectors. While many organizations are investing in VDC tools and processes, there is limited empirical evidence to understand how VDC is implemented in practice and what outcomes it produces. This gap makes it difficult for the industry to establish shared benchmarks, identify best practices, or guide future innovation in VDC implementation.

To address this gap, our research team at the University of Washington partnered with Electri International, John R. Gentille Foundation, New Horizons Foundation, and over 25 companies to conduct an initial exploration of the current VDC landscape. In this analysis, mechanical trades refer to companies involved in HVAC construction, including sheet metal fabrication. We further distinguish between piping, plumbing, detailing, and fabrication activities. Some participating firms specialize in a single MEP trade, while others cover multiple or all MEP disciplines. The size and structure of VDC departments also vary; some firms have large teams with various layers of management, while others operate with small, lean groups.

This collaborative effort aimed to lay the groundwork for developing industry-wide benchmarks and, ultimately, advancing the standardization of VDC practices.

In this initial phase of research, we focused on three key outcomes.

- First, we developed a standardized VDC Task Schema to categorize everyday tasks performed by VDC teams, including 1. Modeling and Shop Drawing Creation, 2. Internal Management and Coordination, 3. External Management and Coordination, and 4. Fabrication Support. This schema, grounded in industry feedback and academic foundations, enables a more consistent understanding of how VDC work is structured across organizations.

- Second, we collected time-tracking data from participating companies to inform the development of benchmarking metrics for VDC performance. This data enabled us to quantify how time is distributed across various VDC tasks and to explore the underlying factors that may influence these patterns (e.g., the role of the VDC engineer, project type, and market sector). Building on this foundation, we extended our analysis to examine the relationship between tasks, roles, and responsibilities within the VDC MEP industry. Specifically, we analyzed how different tasks, roles, and responsibilities are mapped with each other and identified consistency and variability in the VDC MEP industry. Additionally, we examined the emerging trend of automation in fabrication processes and its implications for VDC tasks.
- Third, we identified several challenges in developing a national benchmarking system and motivating consistent participation across companies. While the goal of industry-wide benchmarking is ambitious, it is achievable with the right foundation and collaborative effort. To support future progress, we developed a standardized data format and accompanying resource package that companies can use to contribute to and align with benchmarking initiatives. In addition, we outlined key recommendations to help advance this effort, including developing a streamlined data-sharing protocol and establishing clear data governance practices.

The report is structured as follows: **Section 1 (VDC Task Schema Development)** introduces the VDC Task Schema; **Section 2 (Task Role Responsibility Mapping)** explores task-role-responsibility relationships; **Section 3 (Assessment of the Levels of Automation in Fabrication Processes)** discusses trends in automation for fabrication; and **Section 4 (Tools for Creating National Benchmarking Metrics)** provides recommendations for achieving national benchmarking.

Section 1: VDC Task Schema Development

In this section, we present the definitions of VDC tasks and the structure of the VDC tasks, which organizes VDC-related work into a hierarchical system of levels and standardized terminology. This schema is a foundation for improving communication, consistency, and performance tracking across construction projects. Following the introduction of the schema, we explore its potential implications for the industry, particularly how it can reduce fragmentation, support data-driven decision-making, and enable benchmarking. Finally, we offer practical recommendations for implementation, including integration with time-tracking tools, training strategies, and suggestions for continuous refinement through industry feedback.

VDC Task Schema

To facilitate the development of industry-wide shared VDC task metrics, we developed a VDC Task Schema to define common VDC tasks across the industry (see Appendix A). Working with industry partners, we co-developed and tested the schema, evaluating its applicability in real-world practice and its acceptance within the industry.

The VDC task schema is organized in three levels of detail. At level 1, the schema has four main categories: 1)Modeling and Shop Drawing Creation, 2) Internal Management and Coordination, 3) External Management and Coordination, and 4) Fabrication Support. Each of these level 1 categories is further broken down into more specific tasks at levels 2 and 3. Levels 2 and 3 elaborate and specify the scope of activities within each level 1 category, creating a hierarchical structure that captures the complexity and granularity of VDC workflows. Below, we define each activity with a brief explanation of each term. Please note that some terms were not followed by explanations due to their self-explanatory nature. If further clarification is needed, please refer to the explanation provided for the corresponding lower-level activity.

1. **Modeling and Shop Drawing Creation** (Creating, validating, and managing digital representations of the project's physical and functional characteristics)

    1.1. ***Initial Preparation and Modeling*** (Creating new models)

    1.1.1. **Initial Preparation** (Setting up the modeling environment, including reviewing contractual documents, understanding modeling specifications, and establishing a computerized environment including shared data platforms, grid lines, and file organization systems. For the BIM execution planning, please refer to Create and Refine BIM Execution Plan)

    1.1.2. ***Initial Design & Modeling*** (Creating and converting of preliminary models based on the project's design intent and contract documents)

1.1.3. **Model Validation** (Ensuring the accuracy and completeness of the developed model against the intended design)

*1.2. **Shop Drawing Submittal***

1.2.1. **Shop Drawing Generation** (Generating shop drawings, producing detailed drawings, and adding annotations, dimensions, and tags to these documents)

1.2.2. **Prepare Model for Shop Drawing Submittal** (Preparing a digital model to be submitted as shop drawings. It includes finalizing the design details, annotations, and any necessary specifications within the model to ensure it meets the required standards and accurately represents the construction or manufacturing details needed for approval or further processing)

1.3. ***Model Update and Version Control*** (Making modifications to a digital project model and systematically managing its multiple versions to track changes, preventing data loss, and ensuring that team members are working with the most recent and accurate representation of the project)

1.3.1. **Model Revision** (Making necessary modifications to the model to reflect any design changes; this can be due to RFIs, design change, or 3D coordination)

1.3.2. **Model File Management** (Managing files and security including file backups)

1.4. ***Post-construction modeling***

1.4.1. **As-built model creation** (Updating models to reflect the project's final constructed state for documentation purposes)

1.4.2. **Asset Data Creating and Management** (Establishing and maintaining a record of assets, along with their specific characteristics, such as brand, model, and serial number)

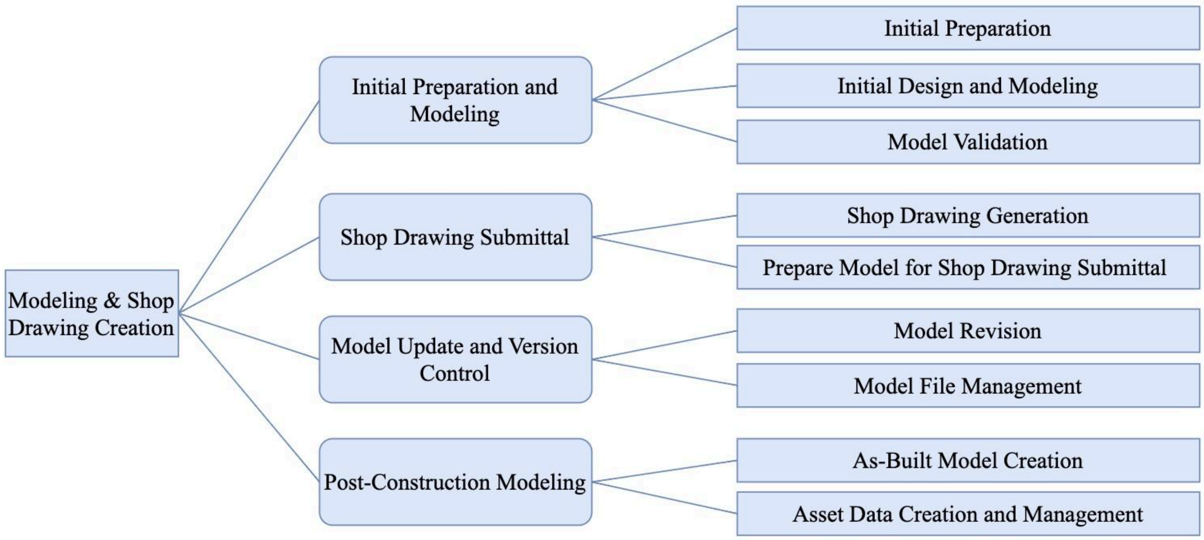

Figure 2-1. VDC Task Schema - Modeling & Shop Drawing Creation

2. **Internal Management & Coordination** (Addressing the organizational aspect of a project, including internal operations and external stakeholder interactions)

   2.1. ***Internal Project Management***

      2.1.1. **Task Assignment and Tracking** (Assigning responsibilities and tracking the status of project tasks)

      2.1.2. **Planning and Scheduling** (Setting up and organizing the project timeline and milestones)

      2.1.3. **Management Guidelines** (Establishing standard procedures for the project, such as change order review and work permit review procedures)

      2.1.4. **Project Progress Reviewing** (Evaluating the project's progress and direction by examining factors such as completion percentage, time invested, and remaining budget)

   2.2. ***Internal Training & Technology Support***

      2.2.1. **Enhance Employee Proficiencies by Providing Regular Training Sessions** (Offering educational sessions to improve worker capabilities and skills. Including both formal and informal peer-to-peer training)

      2.2.2. **Software/System Maintenance & Upgrading** (Ensuring tools and systems remain functional and upgrading if necessary to enhance the system stability)

2.3. Internal Team Collaboration

2.3.1. **Meetings and Workshops** (Organizing and attending sessions for brainstorming and decision-making)

2.3.2. **Internal Communication** (Spending time on team communication, such as writing emails or having phone calls)

2.3.3. **Feedback Loops and Iteration Processes** (Revising and refining every aspect of the project based on team feedback)

2.4. Internal Documentation & Record Keeping

2.4.1. **Document Control and Contract Management** (Managing and maintaining important project files such as design coordination, meeting minutes, and contract control, not including models and drawings)

2.4.2. **Field Survey and Documentation** (Conducting site observations and capturing field data including but not limited to project progress, conditions, and compliance)

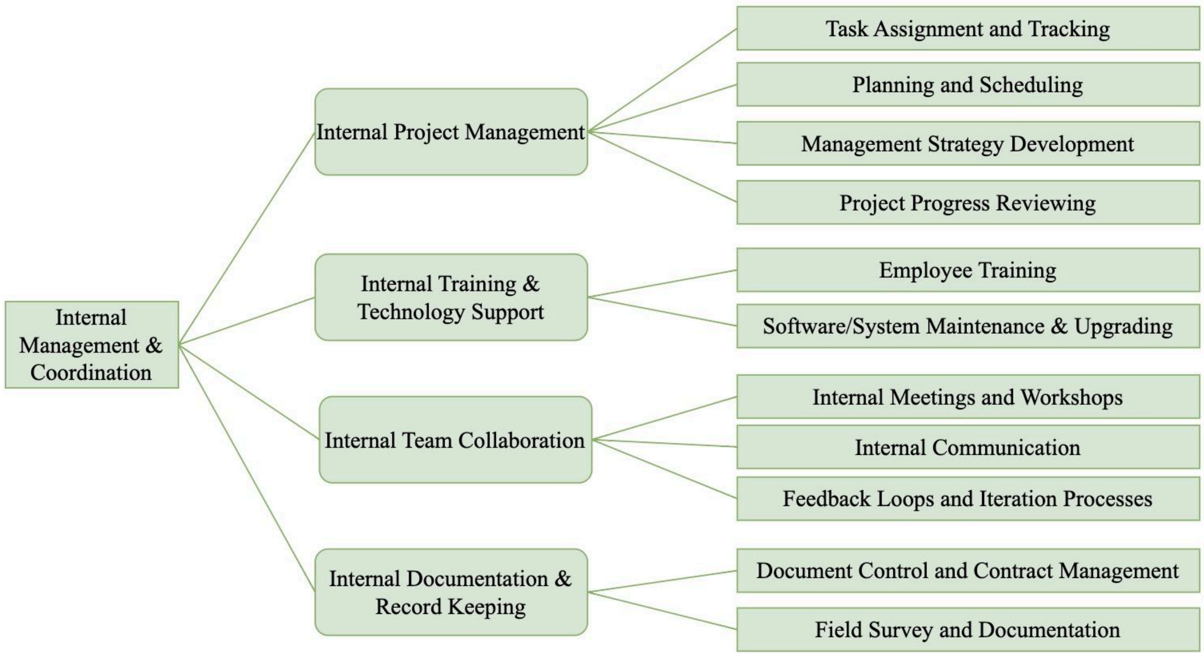

Figure 2-2. VDC task schema - Internal Management & Coordination

3. **External Management & Coordination** (Managing interactions and aligning efforts with external stakeholders such as clients, consultants, subcontractors, and third parties)

   3.1. ***External Stakeholder Management***

   3.1.1. **Create and Refine the BIM Execution Plan** (Planning the essential prerequisites for modeling, delineating the roles and responsibilities, and securing the necessary clearances for the modeling activities within the framework of a BIM execution plan)

   3.1.2. **Gathering Feedback and Concerns** (Collecting input, opinions, critiques, and concerns from stakeholders regarding a project including requirements from stakeholders that might cause a design change)

   3.1.3. **Update Project Progress** (Managing project schedules and informing stakeholders about the project's status. This can be a formal meeting, email, or phone call)

   3.1.4. **Submittal management** (Addressing issues related to submittal and the time to solve the problems)

   3.1.5. **RFIs management** (Writing and responding to RFIs and any other interaction with external people)

3.2. ***MEP Team Coordination and Collaboration***

3.2.1. **Model Federation and Clash Detection** (Federating different models, such as plumbing, electrical, and HVAC, into a shared model environment and identify all clashes; does not include the model revision caused by clashes – see Model Update and Version Control)

3.2.2. **Subcontractor Management** (Overseeing subcontractor performance and ensuring alignment with project standards)

3.2.3. **External Meeting and Workshop** (Setting up and participating in gatherings aimed at generating ideas and making decisions)

3.2.4. **Model Coordination** (Collaborating on modeling with external parties, including integrating third-party models or data into the main project model, Clash Detection, and ensuring third-party compliance with project standards and requirements

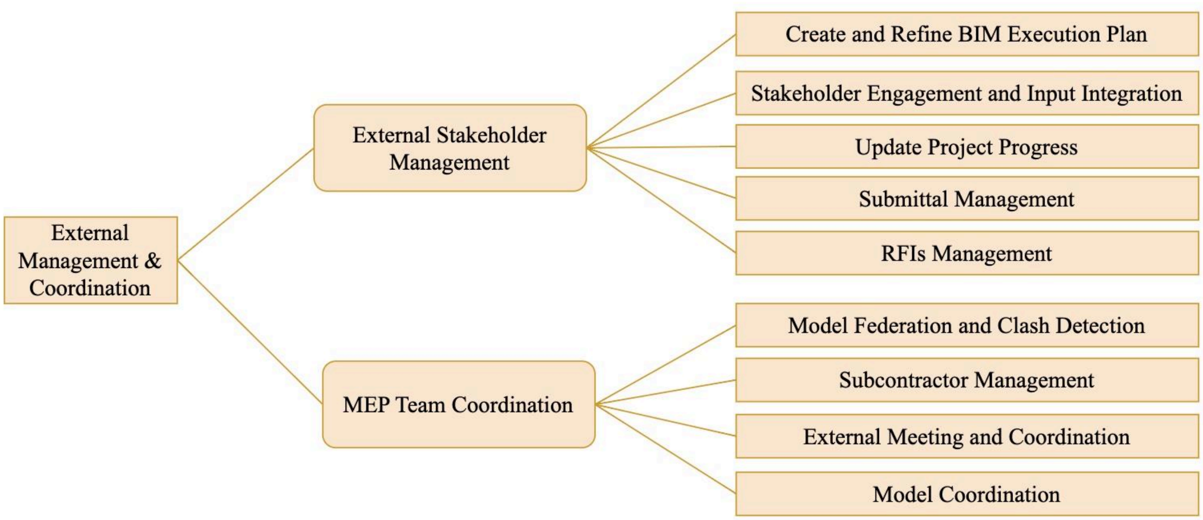

Figure 2-3. VDC task schema - External Management & Coordination

4. **Fabrication Support** (preparing, managing, and integrating information for the manufacturing of the project components)

4.1. ***Preparation for Fabrication***

4.1.1. **Fabrication Drawing Generation and Review** (Producing detailed diagrams for fabrication and installation and coordinating with manufacturers)

4.1.2. **Material Specifications and Procurement** (Defining materials, work packages, creating material lists, and calculating material quantities)

4.2. ***Fabrication Management***

4.2.1. **Workflow and Process Optimization** (Creating an optimal process and timeline to fabricate materials and deliver them to the right place)

4.2.2. **Resource Allocation (Manpower, Machinery, Materials)** (Allocating manpower, machinery, and materials to ensure execution as planned)

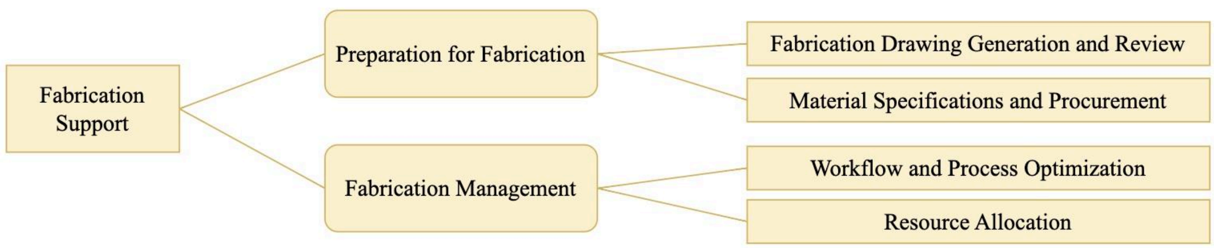

Figure 2-4. VDC Task Schema - Fabrication Support

VDC Task Schema: Industry Implications

The introduction of a standardized VDC task schema demonstrates the potential for standardization across the construction industry as it continues to adopt and mature the VDC processes. By offering a common framework to define, classify, and name VDC activities, this schema addresses one of the industry's persistent challenges—variation in task definitions and inconsistent terminology.

First, the VDC task schema lays the foundation for industry-wide standardization of VDC task structures. It reduces ambiguity in how teams and companies define and describe modeling, coordination, and planning activities. A consistent vocabulary can streamline collaboration, enhance training and onboarding, and reduce miscommunication across trades.

Second, the schema enables companies to track and analyze the time invested in each VDC activity with greater clarity. By aligning internal task lists with a standardized structure, organizations can better understand how time is distributed across different functions. This insight is critical for informed resource allocation, performance assessment, and continuous workflow improvement.

Finally, a shared schema opens the door for industry benchmarking. When multiple firms adopt the same activity structure, meaningful comparisons can be made across projects, allowing for identification of best practices, inefficiencies, and strategic areas for improvement. Over time, this can drive collective progress across the sector and support the creation of data-informed guidelines for VDC implementation.

VDC Task Schema: Practical Recommendations

To fully leverage the benefits of the VDC task schema and accelerate its impact across the construction industry, we offer the following recommendations:

(1) Integrate the Schema into Time-tracking and Project Management Tools

To realize the benefits of improved time and resource allocation, organizations are encouraged to incorporate the schema into their digital tools. Using standardized task schema in time-tracking systems enables accurate measurement of effort spent on specific VDC activities and allows for insights into performance across the schema tasks.

To successfully integrate this schema into time management systems, we recommend initiating a change management process. This includes assessing the impact on existing systems, identifying the organizational adjustments required, and providing adequate training and support to employees to ensure a smooth transition and sustained adoption. Additionally, if your organization does not currently have a time-tracking process or lacks an effective tool for this purpose, we recommend exploring user-friendly solutions such as Clockify, a time-tracking platform we tested as part of this study. Other options include Toggl Track, Harvest, or TrackingTime.

(2) Use the Schema for Training and Onboarding

Once the schema is integrated into organizational processes, it is essential to provide regular training for both new and existing employees. Given that the adoption and refinement of the schema will require sustained effort over time, ongoing training ensures that all team members are informed about the latest updates and are equipped to use the system accurately, particularly for reliable time-tracking.

Standardized activity definitions can also streamline the onboarding process, helping new employees and collaborators quickly understand VDC workflows and reducing confusion during project execution. Incorporating the schema into training programs fosters a shared understanding across teams and supports consistent implementation.

(3) Facilitate Industry Collaboration and Knowledge Sharing

Industry associations, project partners, and all other interest groups should consider adopting the schema as a shared framework for benchmarking. Common definitions enable stakeholders to compare project performance, develop collective best practices, and track industry progress over time.

(4) Refine and Expand the Schema Through Continued Feedback

As companies begin to adopt the schema and apply it across diverse project contexts, we admit that refinements may be necessary to ensure its continued usability and relevance. The initial version of the schema was developed with input from a limited number of companies and may not fully reflect the needs of the broader industry. We welcome and encourage ongoing improvements based on real-world application.

If modifications or expansions are needed, we recommend keeping a clear record of the changes made, along with documentation of the specific context or project circumstances that prompted them. This transparency will support possible justification and future knowledge sharing with the industry.

In addition, we encourage companies to further develop more granular task definitions as needed. While the current schema defines tasks up to Level 3, project teams may find value in breaking these down into more detailed sub-tasks tailored to their specific workflows.

Section 2: Task Role Responsibility Mapping

In today's evolving MEP industry, the Virtual Design and Construction (VDC) department plays a pivotal role in streamlining project delivery. In the VDC department of the MEP industry, three most common roles are: BIM/VDC detailer, BIM/VDC coordinator, and BIM/VDC manager. This study sought to understand how consistently the industry defines the responsibilities of each of these roles. We created a survey to ask industry members to categorize the VDC Task Schema tasks as perform, consulted, oversee, and not applicable for each role of detailer, coordinator, and manager. We found that while some tasks are more clearly assigned to detailers (e.g., perform modeling tasks) and managers (e.g., perform internal and external coordination), many tasks have a mix of responsibilities across the MEP sector we surveyed.

This section presents findings from the analysis of the Task-Role-Responsibility mapping (Figure 3-1) including the trades, experience and, VDC department versus executive management. Roles of detailer and manager seem synchronized with each other but the role of coordinator is standalone. While some responsibilities of a particular role are consistent across the industry, such as performing for the role of detailer in the category of Modeling and Shop Drawing Creation, whereas for others categories such as those in Internal and External Management responsibilities are more varied across the industry. Managers and coordinators are predominantly responsible for perform/oversee and perform/consulted respectively for their tasks. It is noteworthy that there is variation in perception of Task-Role-Responsibility mapping between more experienced (10+) and less experienced (1-5 and 5-10) industry professionals. The understanding of Task-Role-Responsibility between VDC department and Executive Management is similar overarchingly with slight variations in percentages. Furthermore, industry implications of these findings in terms of consistency/variability in Task-Role-Responsibility mapping are outlined. This suggests greater consistency across the industry will lead to benefits such as improved resource allocation and clarity in career progression. Finally, we recommend applications of this study to support team adoption of industry wide standards, clarity of roles and the balance between standardization and customization as it relates to the development of national benchmarking metrics.

Unpacking Task-Role Dynamics in VDC Practice

This section offers takeaways from the VDC Time Study for MEP industry in the context of who (role) is doing what (responsibilities) per tasks (VDC Task Schema). A survey was conducted at the MEP Innovation Conference 2025 that attracts MEP professionals in the US. These industry professionals had 1-10+ years of MEP industry experience. Industry professionals took part in the survey (156 responses) but 66 responses were finalized based on the percentage completion of response (having 77% and above) for the analysis and results. The following Figure 3-1 presents Tasks-Role-Responsibility mapping that builds on the VDC Task Schema (Section 1).

Figure 3-1 exhibits responsibilities defined generally across tasks as perform, consulted, oversee, and not applicable in percentage on y-axis as a 100% stacked column for each VDC Task Schema task on x-axis for three distinct roles of BIM/VDC coordinator, BIM/VDC detailer and BIM/VDC manager. Figure 3-1 offers a current landscape of working practices in VDC of MEP industry, exhibiting trends of responsibilities per task per role, whereas it also exhibits variability regarding responsibilities versus tasks for these roles. Three roles (coordinator, detailer and manager) are undertaking the work in the VDC department. The role of coordinator is involved in performing and being consulted for different tasks, whereas the role of manager is more involved in performing and overseeing those tasks. The role of detailer is to perform 'Modelling and Shop Drawings Creations' tasks and some tasks for External Management & Coordination' (3.1.3 Update Project Progress, 3.2.1 Model Federation and Clash Detection, 3.2.3 External Meeting and Workshop), and 'Fabrication Support' (4.1.1 Fabrication Drawing Generation and Review and 4.1.2 Material Specifications and Procurement), but variable for Internal Management and Coordination, and Fabrication Support tasks (4.2.1 Workflow and Process Optimization and 4.2.2 Resource Allocation).

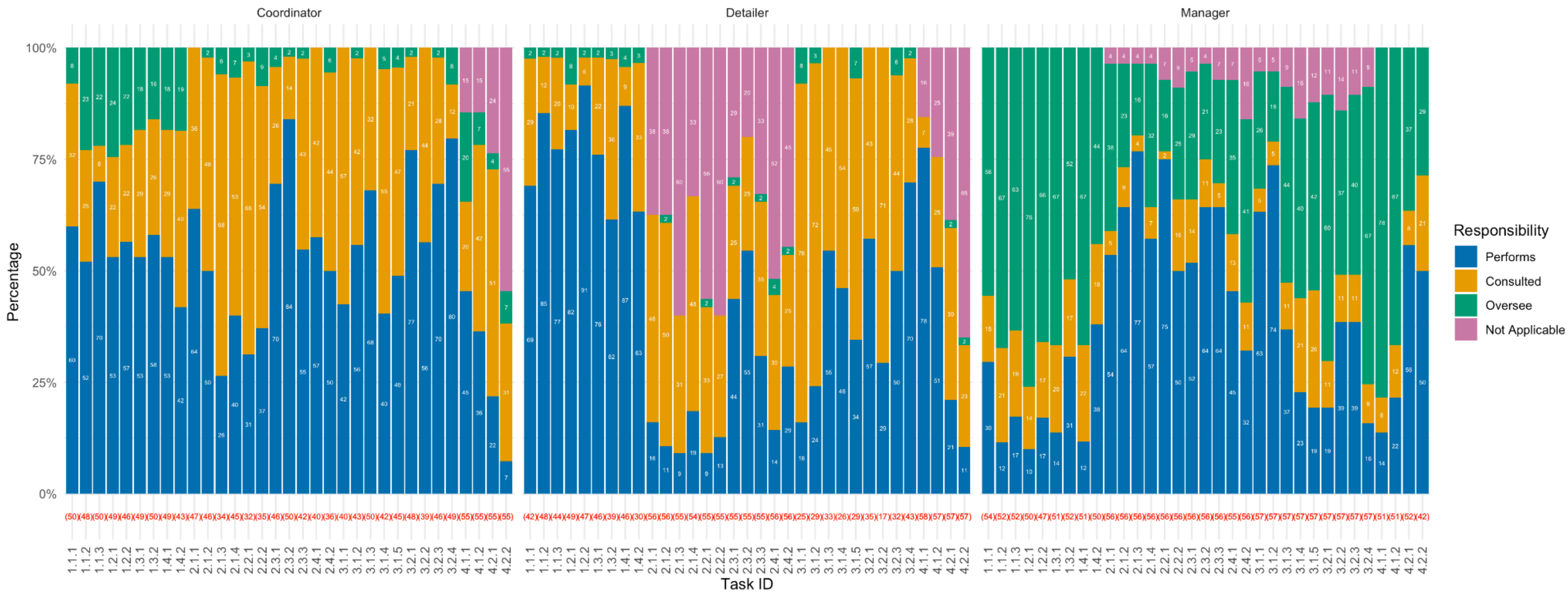

Figure 3-1. Task-Role-Responsibility Mapping

This section presents a high-level summary of the findings. See Appendix B for more detailed analysis.

Relationship between Roles

Overall, it appears that there is a relationship between the role of detailer and manager, whereas the role of coordinator seems to standalone. For instance, for 'Modeling & Shop Drawing Creation' the detailer is performing those tasks and the manager is overseeing them as can be seen in Figure 3-1. Additionally, when the manager is performing tasks in 'Internal Management & Coordination' and 'External Management & Coordination', the detailer is being consulted. However, the role of coordinator is more complex with a strong trend to perform and to be consulted across all task categories. The role of the coordinator may at times take on the tasks of the detailers, while at other times may take on the tasks of the manager.

Responsibility Patterns of Roles

There are particular consistent responsibilities patterns for the roles of coordinator, detailer and manager (Figure 3-1). The coordinator is mainly performing and/or being consulted for the VDC tasks. In the case of detailer the consistent pattern is performed but only related to 'Modeling and Shop Drawing Creation' tasks. The role of manager is performing and/or overseeing consistently for the VDC tasks. There are also some noticeable variabilities. For instance, for the role of coordinator 'Fabrication Support' tasks are variable, and in the case of detailer 'Internal Management and Coordination', and 'Fabrication Support' tasks exhibit variability in the perception of the industry.

Detailer Responsibilities Pattern

While the detailer remains an integral contributor as performer in certain task categories, for instance, 'Modeling & Shop Drawing Creation', 'External Management & Coordination' (3.1.3 Update Project Progress, 3.2.1 Model Federation and Clash Detection, 3.2.3 External Meeting and Workshop), and 'Fabrication Support' tasks (4.1.1 Fabrication Drawing Generation and Review and 4.1.2 Material Specifications and Procurement) there is a mix of responsibilities at other tasks categories, like 'Internal Management & Coordination' and particularly 'Fabrication Support' (Figure 3-1), reflecting variability regarding the responsibilities of detailers across the industry. It is also noteworthy that the role of detailer exhibits the most variability in terms of responsibilities performed among all three roles.

Manager Responsibilities Pattern

Across all tasks categories, for the role of manager, 'Modeling & Shop Drawing Creation', 'Internal Management & Coordination', 'External Management & Coordination' and 'Fabrication Support', the predominant responsibilities of manager are to perform and oversee the tasks being performed, particularly done by the detailer (refer to Figure 3-1). For ‘Modeling & Shop Drawing Creation’ the predominant pattern is oversee, on the other hand, for ‘Internal Management & Coordination’ it is performance. In the case of ‘External Management & Coordination’ and ‘Fabrication Support’ there is a combination of perform and oversee.

Coordinator Responsibilities Pattern

The role of coordinator seems like a standalone role as compared to the relationship between retailers and managers. The coordinator’s role is marked by versatility and flexibility. Unlike the detailer and manager, whose responsibilities tend to follow more predictable patterns, the coordinator frequently alternates between performing and consulted responsibilities ‘Internal Management & Coordination’ and ‘External Management & Coordination’, with occasional oversight for ‘Modeling & Shop Drawing Creation’. This mixed engagement suggests that coordinators often act as connectors or facilitators across teams particularly inter-organizations. Nevertheless, there is variability for the role of coordinator for ‘Fabrication Support’ tasks as ‘not applicable’ is associated with those tasks with a consistently increasing trend from 4.1.1 to 4.2.2 tasks in Figure 3-1.

Roles-Responsibilities vs. Trades

The overarching trends for the MEP trades are the same as Tasks-Role-Responsibility mapping and can be seen from Figures B-1 to B-4 (refer to Appendix B) in comparison with Figure 3-1. There are no clear patterns that distinct one trade from the other MEP trades. Nevertheless, there are some variabilities among the MEP trades, for instance some trades exhibit stronger/weaker responsibility trend regarding a certain role (coordinator, detailer, manager) related to a particular task categories i.e. ‘Modeling & Shop Drawing Creation’, ‘Internal Management & Coordination’ and ‘External Management & Coordination’ and ‘Fabrication Support’. At times some trades express higher percentage values for a particular task as compared to Figure 3-1 Task-Role-Responsibility mapping. The detailed findings are elaborated in Appendix B section B.2.0 Task-Role-Responsibility versus Trade.

Impact of Experience

It appears that number of years of experience plays a role in understanding the job description, working practices and team working dynamics (refer to Figures B-5 to B-8 in Appendix B). The pattern of responsibilities shown by 10+ years of experience resonate with the pattern of responsibilities in Figure 3-1. On the other hand, less experienced professionals i.e. 1-5 and 5-10 years of experience present some deviations as compared to more experienced professionals (10+). This indicates variation in the understanding of shared working practices across the project teams.

VDC Department vs. Executive Management

Data of survey is also analyzed in terms of roles of the survey participants in the MEP industry. Roles of the respondents like VDC detailer, VDC coordinator and VDC manager are categorized as VDC department. On the other hand, other roles of the respondents like owner, business analyst, VP operations etc. are categorized into executive management. This comparative analysis is to find out the perception of both groups about Tasks-Role-Responsibility mapping as their understanding of the mapping might have an impact on the organizational performance on projects. Although the overarching trend remains the same when comparing the perception of VDC department and executive management, there are some mismatches in the holistic comprehension of responsibilities being taken by different roles between VDC department and executive management (refer to Figures B-9 to B-12 in Appendix B).

Task Role Responsibility Mapping: Industry Implications

The goal to create national benchmark metrics for VDC tasks in MEP coordination brought forward the need for greater clarity in how companies assign tasks, define roles, and distribute responsibilities. The integration of VDC Task Schema—mapped against defined roles and associated responsibilities as Tasks-Role-Responsibility mapping—presents several key implications that directly address the challenges of fragmentation, misallocation of time and resources, and role ambiguity in the MEP workflows. Integration of VDC Tasks Schema with roles and responsibilities support bridging fragmented understanding in resource allocation to VDC tasks. This would enhance better resource allocation by reducing under/over allocation of resources, clear expectations, proper workload and subsequent improved team performance. Also, consideration of the fact that responsibilities are dynamic in nature i.e. perform, be consulted and oversee would better develop the sense of time being spent on different things by the coordinator, detailer, and manager. This will also bring clarity to the expectation of the organization and to the job roles, thus subsequently improving team collaboration. Standardization in industry wide roles and responsibilities will be a stepping stone towards performance metrics that can help in comparing productivity and best practices that will eventually lead to the development of industry wide national benchmarking.

Industry Fragmentation

The inclusion of defined roles within the VDC Task Schema helps mitigate the industry's fragmented understanding of resource allocation. By identifying a shared understanding of roles and responsibilities for VDC tasks, the industry can move towards a standardized model for role definition. This foundational step towards a common understanding and practice reduces ambiguity, fosters consistency, and promotes informed decision-making in project management and workforce development.

Enabling Accurate Resource Allocation

Understanding who (role) is accountable for what (responsibility) across the VDC task categories, ‘Modeling & Shop Drawing Creation’, ‘Internal Management & Coordination’, ‘External Management & Coordination’ and ‘Fabrication Support’, will significantly reduce the risk of misallocation or over allocation of resources. The Task-Role-Responsibility mapping in Figure 3-1 suggests that the industry could create a more clear understanding of daily task ownership, ensuring that workload expectations align with performed job functions. As a result, organizations can allocate tasks with greater precision and support balanced team performance.

Recognizing Time Allocation Variability

Tasks-Role-Responsibility mapping (Figure 3-1) differentiates between responsibility types—Performs, Consulted, Oversees, and Not Applicable—which introduces insight into time allocation per tasks for each role. By understanding how different types of responsibilities influence the time invested in a task, project teams can better anticipate effort, plan resources, and reconcile discrepancies between expected and actual time spent. Furthermore, lack of standardized roles and responsibilities in the MEP industry creates a challenge within project teams since different organizations have different roles and responsibilities. This variability in roles and responsibilities in the industry would result in a complex situation within project teams, where different organizations have differing expectations from their resources, thus creating more complexity for the project manager to align expectations of the project and the project team within so much variability. This facilitates more accurate scheduling and forecasting at both the project and executive level.

Clarity and Career Progression

Explicitly outlining VDC-related roles such as detailer, coordinator, and manager, along with their responsibility types, enables better definition of job descriptions and functional boundaries. This structured clarity improves internal communication, streamlines task handovers, and supports more effective collaboration among team members. Moreover, it forms a transparent foundation for performance evaluation, accountability, and career development—motivating teams toward higher engagement and growth.

Industry-Wide Benchmarking

The VDC Tasks-Role-Responsibility mapping also opens opportunities for industry-wide benchmarking. More consistent roles and responsibility definitions across the industry provides a common framework to develop performance metric systems that allows MEP firms to compare operations, productivity, and collaboration practices with peers. These shared reference points promote dialogue around best practices, support strategic improvement initiatives, and ultimately contribute to elevating industry standards as a whole.

Industry-Wide Advancement

The implementation of a structured Task-Role-Responsibility mapping with the VDC Task Schema presents a significant opportunity for transformation across the MEP industry. It addresses longstanding challenges related to fragmented role understanding, misaligned expectations, and inefficient task allocation. Through improved clarity, consistency, and accountability, this framework serves as a foundation for better project execution, team development, and industry-wide advancement towards national benchmarking metrics.

Task Role Responsibility Mapping: Practical Recommendations

Task-Role-Responsibility mapping offers the MEP industry an approach to improve operational efficiency, workforce clarity, and industry-wide collaboration. To fully realize these benefits, organizations in the MEP industry are recommended to take the following strategic actions.

Optimize Resource Allocation

Adopt Tasks-Roles-Responsibility mapping to manage resource allocation and time allocation for accurate expectations. Extend VDC Tasks Schema with roles and responsibilities mapping to see a bigger picture for the VDC tasks. Identify the gray areas related to VDC tasks, roles and their responsibilities. Appreciate the fact that there are different types of responsibilities i.e. performs, consulted and oversees, being done by a role while deployed on tasks as compared to thinking of singular type of responsibility per task. It is suggested to be mindful that undertaking these different types of responsibilities while working on tasks consumes time. Consequently, use this Tasks-Role-Responsibilities mapping to redefine tasks, resource and time allocation. This change in paradigm for tasks, resource and time allocation will yield better allocations and expectations for the VDC tasks in the MEP industry.

Foster Team Adoption

Implement Tasks-Roles-Responsibility mapping as a team in the VDC department of MEP industry to improve workflow, communication and collaboration. Adoption of Task-Role-Responsibility mapping should be done as a team to fully reap the benefits of the extended VDC Tasks Schema. The team has to deliberate together and integrate in the present working practices to bring in clarity and to take ownership of the process. This could be done by looking at the already existing processes and how this mapping could fill in the gaps in terms of improving the already existing workflow. The process of working together as a team to improve the existing workflow would not only improve the workflow, but communication and collaboration as a team during this process and beyond, which will also extend to the working practices of the whole VDC department.

Clarify Role for Growth

Clear expectation leads to clear job roles and career progression that will attract talent to the MEP industry. Implementation of the Tasks-Role-Responsibility mapping will not only bring clarity to resource allocation and time allocation to the given tasks from an executive perspective, but also makes job roles clear for the human resource. Once the workforce has a better understanding of their job role and expectations from them, they can work with focus and precision, thus in turn improving the productivity of the employees. Furthermore, it will reduce the burnout due to miss allocation or over allocation of varied tasks that are out of the capacity and capabilities of a particular role. Overall, refining the role and responsibilities with accuracy saves valuable time that could be utilized at the right tasks. These working practices would generate clear expectations from the management to the employees and the employees would have lucid career progression, which is a strong motivator of productivity at individual level.

Customize per Trade

Refinement and adjustment of Tasks-Role-Responsibility mapping supports industry wide national benchmarking. The MEP industry is a combination of different trades like Mechanical, Electrical, Plumbing and Piping. These different trades have their differences as they deal with different technical work. Due to this variability in the work of these trades, it is recommended to refine and adjust the Tasks-Role-Responsibilities schema for the best fit to a particular trade. Once the variability is captured and set for a particular trade, then industry wide benchmarking of the schema would be possible per trade.

Section 3: Assessment of the Levels of Automation in Fabrication Processes

The primary goal of this section is to assess the current industry practices regarding automation related to fabrication support tasks in the MEP industry. Based on the interviews with the industry experts, there are different levels of automation in the MEP industry. There are a variety of levels of automation across the MEP trades. Some sheet metal production has advanced levels of automation, such as direct digital exchange between models and fabrication equipment. In contrast, others have manual tasks related to creating documentation from models for fabrication. All the companies from the MEP trades we interviewed utilize 3D models for drawings and documentation, particularly shop and fabrication drawings. Nonetheless, there is a variability in how much the production process of these drawings and documentation is further automated, i.e., produced by humans versus automation. Companies have automated tasks such as creating a bill of materials and ordering parts.

One of the biggest challenges of automation is interoperability. The industry has several approaches to address interoperability, including creating configurations at the back end using APIs, coding, scripting, in-house/off-the-shelf customized solutions. These require expertise, beta testing, debugging, and trial-and-error periods. Nonetheless, technology keeps changing; thus, the industry needs constant upgrades to solve ongoing and emerging interoperability issues. Furthermore, there is no one-size-fits-all automation solution, and the industry is using customized software packages like Stratus and Drawer AI integrated with Revit to achieve specific results. One company eliminated redundancy by developing a 3D model-based workflow to produce drawings and documentation. The company has also integrated this 3D model-based workflow with SQL servers to give access to information as and when required. Moreover, the company automates repetitive tasks as they have in-house developers who developed customized tools to automate tasks. The MEP industry can use customized in-house/off-the-shelf software to solve its pressing challenges. Clear Tasks-Role-Responsibility mapping in the context of the level of automation is necessary for industry-wide benchmarking. This variable level of automation across the industry might influence time allocation for VDC tasks and national benchmarking metrics of the MEP industry.

This section presents results, implications, and recommendations for the MEP industry about automation levels in fabrication support tasks. We have drawn from five interviews conducted with industry participants who have between 5 and 24 years of experience in the MEP industry. The details of the interview participants are given below in Table 5.1, showing a representation of all MEP trades. All the respondents are working as BIM/VDC Managers. This section focuses on (1) defining what is automated and how automation relates to the goal of creating VDC metrics, and (2) drawing and document typology, i.e., shop drawings, fabrication drawings, and as-built drawings, in relation to VDC metrics.

Table 4.1: Details of Interview Participants from Industry

Interviewee	**Role**	**Trade**	**Experience (Years)**
MEP Manager	BIM/VDC Manager	MEP	15
Plumbing and Piping Manager	BIM/VDC Manager	Plumbing and Piping	11
Electrical-1 Manager	BIM/VDC Manager	Electrical	17
Electrical-2 Manager	BIM/VDC Manager	Electrical	05
Electrical-3 Manager	BIM/VDC Manager	Electrical	24

Better Understanding of Automation in Fabrication

This section presents the interview results regarding the automation levels for fabrication support tasks. First, we will discuss tasks that MEP subcontractors automate for fabrication support. Then, we discuss drawing typologies and their relation to the VDC Tasks Schema.

Task Automation

In the interviews, the subcontractors discussed how they automated fabrication support tasks. First, they automate the production of drawings and documentation. They also automate the preparation of the bill of materials and prepare for procurement. To do this work, the subcontractors leverage in-house tool palettes, address interoperability issues between software packages, make decisions about leveraging off-the-shelf products vs designing software in-house, and further develop model-based workflows that extend past the 3D coordination efforts and shop drawing creation.

Utilize 3D Models to Produce Drawings and Documentation

All the respondents reported using 3D models as the basis to produce drawings and documentation. The details in the drawings increase from shop drawings to as-built drawings, but they all build on the information in the 3D model. These workflows relate to 1.2.1 Shop

Drawing Generation, 1.2.2 Prepare Model for Shop Drawing Submittal, and 4.1.1 Fabrication Drawings Generation and Review tasks in the VDC Tasks Schema.

The MEP Manager stated that preparing, coordinating, and generating drawings like shop drawings, spool drawings, spool map, fabrication drawings, and as-built drawings is automated using 3D models. The basis for these drawings is a 3D model, but the level of detail differs for different types of drawings; for instance, the level of detail increases from shop drawing to fabrication drawing.

The Electrical-1 Manager expressed that his company upgraded from AutoCAD (2D) to Revit (3D model) and further enhanced the level of information in the base Revit model by integrating a customized add-on. This shift addressed the project requirements for Revit, and almost 90% of their work is now with Revit. The shop drawings contractually required by the General Contractor (GC) for onward submission to the owner for record, are done through Revit. Also, the level of detail this company used to have in the shop drawing, as compared to eight years ago when they primarily used 2D AutoCAD, has significantly increased. Additionally, they utilize Navisworks to view information better, and field staff can access these models. However, the company does not train field staff to use BIM models or Navisworks, so they also import 2D drawings (outputs from the 3D models) into Bluebeam as a PDF viewer. Consequently, fabricators mostly use PDFs in Bluebeam that can be marked up or printed out in A2 size and shipped to the site for installation.

The Electrical-2 Manager described their process. Once the detailers finish model coordination, they initiate two sets of drawings: fabrication and installation. Detailers use Revit and Navisworks for these tasks. First, they make assemblies in Revit and group them in bigger portions called kits. After modelling kits, electricians do the Quality Control (QC) check to ensure constructability. Afterwards, detailers create fabrication drawings for kits. Electricians conduct another QC of fabrication drawings at this point. Once the check is done and passed, the detailers share the fabrication drawings with the fabrication shop. Basic Revit and manual human checks predominantly govern this electrical subcontractor's workflow to ensure that things are going in the right direction. Subsequently, detailers generate a bill of materials from those approved fabrication drawings. On the other hand, after the approval of coordination drawings from the engineer, installation drawings are also done for the field crew as a supplement document for the field work at the site. Lastly, the field crew uses a total station to deploy installation points on site.

The Plumbing and Piping Manager shared that their company uses Revit and Stratus for the 3D modelling and publishes those models on Procore to the project team. After detailers finish coordination, they produce shop drawings for internal and external approvals. Once the shop drawings are approved, they build on them to develop fabrication drawings, spool sheets, and maps for the fabrication shop. Furthermore, detailers also produced installation drawings to support field crews. These spool maps, layout drawings, and installation drawings are internal working documents that help fabrication and field crews. On the other hand, submittal drawings are prepared and submitted as part of the structural requirements to verify openings in the deck. So, all these drawings and documentation are based on 3D models that get published and then moved to the fabrication shop for fabrication support, and subsequently to the field crew as installation drawings.

The Electrical-3 Manager outlined that their company generates shop and spool drawings from the 3D models after coordination. The subcontractors are contractually required to submit shop drawings to the engineer of record. According to the Electrical subcontractor, shop drawing submission is also a milestone to show work progress by a specific date. On the other hand, detailers make spool drawings for fabrication in the shop. Shop drawings are contractually required, whereas other drawings, like spool drawings, are for fabrication support and to support subcontractors' fabrication and field crews. Consequently, while there may be exceptions for large, complex projects, the subcontractor does not typically submit spool drawings for external approvals.

Prepare Bill of Materials Using Customized Software

The MEP industry uses 3D models to prepare bill of materials so that the information is accurate and redundancy in the workflow is reduced. Furthermore, a company integrated 3D models with customized tools to extract bill of materials from their models and automate ordering of parts**.**

The MEP Manager explained that they have automated their process of calculating material quantities and billing, which they send as a purchase order for procurement. The manager stated, "*...custom software to SQL servers that take our bills and material and send them directly to purchasing spool, hosting so that they can be seen from multiple people, not just in one location, but server-based.***"** In addition to automating the bill of materials, the MEP Manager revealed that they automate procurement using an SQL server to order parts. The MEP Manager stated: "*...we use custom SQL servers for procurement and ordering of parts.*" The bill of material and procurement is related to 4.1.2 Material Specification and Procurement tasks, that is performed by detailer, consulted with coordinator and overseen by the manager as represented by the Task-Role-Responsibility mapping in Figure 3-1.

Both Electrical-1 Manager and Electrical-2 Manager explained that detailers develop the material list from the 3D models, after they create the fabrication drawings. The electrical subcontractors we interviewed did not report using software or plugins to carry out a bill of materials. Still, the detailer creates the material list once they finish the fabrication drawings using 3D modelling from Revit, so the bill of materials is not being done from scratch manually or from 2D printed fabrication drawings. So, there is no redundant work right from the start. The detailer extracts this information from the already created information sequentially, which means the production of a bill of materials builds off of finalized fabrication drawings after the quantity control checks.

Development of Customized In-house Tool Palette

The MEP industry can benefit from in-house development capabilities. The respondents revealed that they solved industry wise specific problems using customized tools developed in-house. Also, custom tools are developed and used to automate repetitive tasks.

The MEP Manager explained that they work with an in-house developer to develop and maintain automation. This aligns with task 2.2.2 Software/System Maintenance & Upgrading in the VDC Activity Task schema. This MEP company continues to find new ways to automate workflows across the design, fabrication, construction, and operations processes. The company has an in-house tool palette and panel developed by their software developer as per their needs, for instance, automatically tagging hangers, tracking views, and inserting parameters on parts. The MEP manager expressed, "*So we have a whole tool palette that we have a software developer that works for us, and actually a couple of them, but one main one that's in our group, and they do all kinds of things. I mean, whatever we need them to do, if we need a hanger tool, they will develop a hanger tool from scratch. It just takes time for them to figure that out and we have an entire tool palette and a panel that comes up that does everything from throw tags on automatically to hangers on to track views to put and insert parameters on parts and I mean it's a pretty comprehensive tool palette that our software developer uses.*"

Adopted customization for Interoperability

The MEP Manager affirmed that interoperability issues of technology are a challenge. "*Nothing's ever seamless unless we manage it to work with our system…So we're trying to get systems to talk that don't necessarily natively talk.*" The MEP Manager explained that they address this challenge related to 2.2.2 Software/System Maintenance & Upgrading by addressing interoperability, such as modifying the output of one software (from a vendor) compatible as an in-put to the other software package (from another vendor) and formulating a seamless workflow to work with models and produce correct information for the right user in a way to support their tasks. The MEP Manager explained, "*Now each one of those steps required an immense amount of back-end APIs and software development to get everything to talk correctly and to report correctly, and done a decent trial period with debugging. And trying to break it, and then when we finally go into actual use, it's a decent amount of bugs that we'll find throughout that process too. But it's there's not an out-of-the-box as far as I'm aware. It's not like Revit can do all of this, or I mean, we're using fabrication on top of Revit with M suite or Stratus into our SQL Server to even get it to the shop, so it's so many parts and pieces to get the automation to work. It's not just one thing.*"

The Plumbing and Piping Manager echoed the interoperability issues. Their company has configured their software packages to exchange data between the platforms seamlessly. Initially, there were interoperability issues between the packages, but those interoperability issues were solved by doing 'configurations'. He said, "*There's obviously a configuration that occurred with* *that software when we set it up, but now that it's set up, there isn't a configuration that you need to do each time you publish. It's just you click publish and it goes there and it all works because it's already been configured back when we integrated the two softwares. So I think that's what you're getting at. I mean, for example, right now our publishing, like I said, is that somebody has to push a button. Right now, that software doesn't let you schedule publishes, which would be cool to have.*" Once the detailers finalize the 3D model, they publish it and share it with the fabrication shop. Detailers then create fabrication drawings, spool sheets, maps, and installation drawings.

Integration of 3D models with Off-the-shelf Software/In-house Software Technology

One-size-fits-all technology solutions aren't comprehensively working for the MEP industry. The industry is adopting customized software and tools-integrating with their authoring software packages-to achieve their desired outcomes.

The MEP Manager revealed that integration of the 3D model in Revit to Stratus allows the fabricator to get the information as needed, to reduce the RFI and time delay required to get the clarification. He stated, "*They [fabricators] could potentially click on that and get that information out of the model directly, and that's because we've automated now from Revit through Stratus and given them the ability to view those parts.*" This is related to 2.2.2 Software/System Maintenance & Upgrading and 4.2.1 Workflow and Process Optimization.

The Electrical-2 Manager declared their Revit to Drawer AI for dimensioning and modelling. They mainly used two platforms, Revit and Navisworks. Another tool called Drawer AI is in the testing stage to automate the modelling and dimensioning, which would be an upgrade and automation related to tasks 2.2.2 Software/System Maintenance & Upgrading and 4.2.1 Workflow and Process Optimization, respectively. He said, "*That part is still kinda what's in the works. Like, we haven't really fully deployed Drawer AI yet. It's more of a test case scenario 'cause we've been manually doing most of this. But when it is, when it does go off to that extra software, ideally, it's coming. It's just taking the model and it's doing the modeling or the dimensioning and all that by itself.*"

The Plumbing and Piping Manager outlined their integration of Revit with customized rules within the software for some automatic functions. He affirmed that their company has customized automation on top of software packages like Revit to build deliverables from the 3D models, or to do initial modelling work to develop spools and assemblies for the spool drawings and spool maps. However, this automation is not autonomous because what it produces will not be considered accurate until a manager conducts a QC check. This check is necessary to see that everything fits well per the field installation's requirements.

Electrical-3 Manager explained their automation of Revit with in-house Dynamo scripting for repeatable work. They automated repeatable tasks using those scripts. They use dynamo scripts developed in-house to automate tasks like preparing drawing sheets, placing views on sheets, and schedules. They integrate authoring software Revit with in-house developed scripts to automate the repetitive aforementioned things related to 2.2.2 Software/System Maintenance & Upgrading and 4.2.1 Workflow and Process Optimization in the VDC Task Schema.

Development of Model-Based Workflow

MEP Manager explained their model-based workflow, which eliminates redundancy by recreating the information rather than building on the same information. He shared, *"...design something in a model and then they'll print it out into a PDF or into paper. And then we recreate it into a model. And then we print it out back onto paper, and then we send it to the shop, and then they make it into 3D, and it's like, why are we going to paper so many times? Why are we being so manual on this? It could be a seamless model that we get from engineering that instead of redrawing it, we just modify it to be constructible, and then once we're done with that, it just goes to the shop and they have the ability to see that without any spooling or fabrication drawings because the software has said, hey, this is where it should be. The detailer indicated these are the spool breaks, but we're not creating paper anymore. We're not wasting time. We have like 40% of our time doing annotation and the annotation is just telling somebody else what your model is. Why can't the model tell somebody what it is?*" It is more efficient to have an automated flow of 3D models from design to shop drawings, fabrication drawings, and potentially As-built drawings. This workflow encompasses 1.1.2 Initial Design and Modelling, 1.2.1 Shop Drawing Generation, 4.1.1 Fabrication Drawings Generation and Review, 4.1.2 Material Specifications and Procurement, and 4.2.1 Workflow and Process Optimization tasks.

Drawing and Documentation Typologies

All respondents agreed to use, one way or the other, shop drawings, fabrication drawings, detailing, dimensioning, spooling sheets, spool maps, cut sheets, field drawings, material list, and As-built drawings. Contracts often require shop drawings and as-built drawings submittals, whereas other drawings are for internal use and approved internally to support their work, such as spool drawing, fabrication drawings, and material list for material procurement. Furthermore, field drawings and spool maps support the field crew's work efficiently on site.

The following section explains the development of drawings and documentation, from shop drawing to spool drawing and spool maps, to fabrication drawings, field drawings/installation drawings, and As-built drawings.

MEP Manager explained, *"Shop drawings are a picture of that model that allows engineers and other people who don't have model access to. You need shop drawings to be like on record for a project. They're just a snapshot in time of that model."* He further expressed that spool drawings and maps for sheet metal, plumbing, and piping are intermediary steps between the generation of shop drawings and fabrication drawings. Although shop drawings are the basis for fabrication drawings, there is a difference in the level of detail between shop drawings and fabrication drawings. Fabrication drawings are more granular than shop drawings. Fabrication can't be done based on the shop drawings because they are different. While there is no stand-alone task for the spool drawings and maps in the VDC Tasks Schema, those drawings are part of the 4.1.1 Fabrication Drawings Generation and Review task.

Electrical-1 Manager agreed that contracts usually require shop drawings. Other documents that the detailers produce are generally for internal purposes, such as supporting fabrication in the warehouse and shipping it out to the site.

Electrical-2 Manager revealed that they produce fabrication and installation drawings approved by internal electricians as QC mechanisms. Furthermore, the engineer approves the coordination drawings. Also, the detailer produces a bill of materials/material list and other drawings like detailing, dimensioning, spooling sheets, and cut sheets.

Electrical-3 Manager affirmed that their company prepares many drawings, such as shop drawings, detailing, dimensioning, spool sheets, cut sheets, field drawings, and material lists. Subcontractors submit contractually required shop drawings, which the engineer of record approves. Other drawings, like spool drawings, are for internal work to support fabrication in the fabrication shop. Furthermore, detailers also generate field drawings to support field crews on site. These drawings are internally validated and approved and usually do not require submission to the engineer of record. However, in some cases, if the nature of the project is large and complex, the subcontractor may submit spool and field drawings, but that is not a typical practice and is relatively rare.

The MEP Manager stated that they generate As-Built drawings from the marked-up shop drawings sent back from the field, representing any changes on site during construction. As-Built drawings creation tasks 1.4.1 As-Built Model Creation is 'performed' by 'detailer' and 'overseen' by the manager, as evident from the Figure 3-1 Task-Role-Responsibility mapping.

Levels of Automation

Defining levels of automation in MEP detailing and fabrication is complex and multifaceted. It means different things to different MEP trades. However, one schema that can categorize the level of automation in the MEP industry is manual, hybrid, and automated. The level of automation for Electrical-I Manager means that they can build everything in the model in their warehouse, ship it, and install it at the site. After producing components from the model, they want real-time tracking of the components, like in the warehouse, shipping, and installing at the site. This company's highest level of automation meant developing 100% of the components in the warehouse and shipping them to the site. They achieved 70% of that goal during the interview. To categorize the level of automation for the company, Electrical-II Manager agreed that defining the levels of automation as manual, hybrid, and automated worked for their company.

For the Electrical-II Manager, automation was software workflows that can perform independently of human interaction with accuracy, and that can also integrate with other systems. The differentiating factors between higher and lower levels of automation are cost and time. The higher level of automation should be cost-effective in the long run and reduce work time. Electrical-II Manager categorized the operations of his company as manual, hybrid, and automated. However, the Electrical-II Manager and Plumbing and Piping Manager also noted that there is a trust deficit related to technology in the construction industry; if the technology can do things it is projected to perform. The Plumbing and Piping Manager believes that the level of automation is something that can reduce and/or eliminate human input for tasks. The higher the level of automation, the higher the output with fewer people and vice versa. The manager agreed that the levels of manual, hybrid, and automated work define the level of automation for their company. Electrical-III Manager pointed out that achieving a certain level of automation depends on the tasks you include in the analysis. If the job is one-off or not often, then there is no justification to automate that. In contrast, if there is something that is the bread and butter of the company, then increasing the automation level has strong justification. Nonetheless, it will be a combination of doing some tasks manually and with the help of technology, so schema 2 (manual, hybrid, and automated) made sense to this interviewee. MEP Manager recognized that defining levels of automation is multifaceted and differentiated the level of automation based on human cognitive input, risk of human errors, time, and accuracy. A lower level of automation would require a higher level of human cognitive input, leading to a higher risk of human errors and more time consumption to achieve accuracy. On the other hand, a higher level of automation would incur less human cognitive input, which means a lower risk of human error, and faster execution of work with accuracy. Thus, the level of automation in the MEP industry is a complex phenomenon that means different things to different companies based on their requirements. Nonetheless, those we interviewed concurred that a three-level schema manual, hybrid, and automated, works well for the MEP industry.

Levels of Automation: Industry Implications

This section outlines the implications of automation levels in the MEP industry. It emerged from the interviews that different companies have different automation levels. On this spectrum of automation levels, companies dealing in Electrical trade are on the lower side of automation and need more research, whereas one company dealing in all three MEP trades is on the higher side of the automation by extensively using technology to do repetitive tasks, solving interoperability issues, and using model-based workflow. This spectrum of automation level might influence time allocation of different tasks, roles, and responsibilities undertaking those tasks, thus resulting in variability in the MEP industry.

Automated Procurement System

The MEP Manager explained their automated system regarding the bill of materials, procurement, and ordering of parts. The variability related to task 4.1.2 Material Specifications and Procurement regarding responsibility is shown in Figure 3-1 Task-Role-Responsibility mapping. As we discussed the results of the metrics in workshops with industry representatives, they hypothesized that the fabrication support tasks such as Tasks 4.1.2 Material Specifications and Procurement, would vary depending on the company's level of automation of these tasks. In our interview, the MEP Manager stated that they had high levels of automation to procure and order materials and parts . Having high levels of automation would reduce the work of a particular role to create material specifications in Task 4.1.2 Material Specifications and Procurement. Taking the data together, when we look at task 4.1.2 Material Specifications and Procurement (refer to Figure 3-1 Tasks-Role-Responsibility Mapping). We observe high levels of variability in role and responsibility for this task. The fact that different companies have different levels of automation, may be the differentiating factor for this role and responsibility variability.

Automation Through Customization

Referring to Figure 3-1 Tasks-Role-Responsibility Mapping for the Task 2.2.2 Software/System Maintenance & Upgrading, it seems that manager performs (50%), and the coordinator and detailer are consulted (54% and 27% respectively). For some, this task was listed as 'not applicable' for the role of detailer. We note that managers do not often perform the development of technology, but rather managers often set requirements for development and carry out gap analysis in technological capability required to perform their tasks in consultation with coordinators and detailers. The higher the level of automation a company wishes to achieve, the more customized options it may look into and develop along the way to a point that they have an in-house customized tool palette. This tailored customization befits a company's needs, and seems better suited than off-the-shelf software packages. But managers should work with the team to fully understand the team's needs, the company's business, and their clients to have a better sense of technological system upgradation with a holistic approach.

Automation in Modeling

Integrating 3D models with in-house or off-the-shelf software to automate repeatable tasks would support generating and disseminating detailed information. The MEP Manager related that having access to detailed information with the integration of Revit and Stratus to fabricators would reduce RFIs, which in turn saves time and eliminates redundancy in the workflow. On the other hand, the Plumbing and Piping Manager explained that their company automated initial modelling, doing detailed dimensioning, and preparing drawing sheets, placing views on sheets, and preparing schedules through integration of in-house/off-the-shelf software. This automation would support 'Modelling and Shop Drawing' tasks by detailers (see Figure 3-1 Tasks-Role-Responsibility mapping).

Automated Drawing & Documentation Production

There are many different types of drawings and documents that companies produce in the MEP industry. Shop and as-built drawings are contractually required from the subcontractors, whereas other drawings, like fabrication and installation drawings, are for internal working purposes. It is noteworthy that automation of tasks like detailing, dimensioning, procurement, bill of materials, solving interoperability, etc. are more related to internal working as compared to external working, i.e., shop drawing and as-built drawings. Automation level achieved by these companies to produce drawings and documents, keeping in view their needs, ultimately supports the execution of work, thus, subsequently, the overall performance of the company in dealing with the projects. However, those companies that have limited to no automation would impact their performance in dealing with the projects.

Levels of Automation: Practical Recommendations

Many opportunities, in terms of technology and processes, can improve the MEP industry's VDC departments effectiveness and efficiency. The findings of the interviews suggest different technologies and processes that can help the industry. Companies have adopted off-the-shelf technologies, for instance, Stratus on top of Revit, to have greater details from the 3D models to support fabrication. Additionally, companies use in-house software developments using Dynamo scripts and coding to automate repetitive tasks. On the other hand, a complete model-based workflow, revealed by MEP Manager, is an attempt towards holistic improvement of the processes. Upgradation of present systems in a way that they integrate with new systems by solving interoperability issues, removing redundancy of re-doing work during the process of fabrication by adapting to a 3D model-based workflow with clear Task-Role-Responsibility mapping would enhance the performance of the MEP industry.

Automation-Based Time Allocation

The MEP industry might also need to consider automation levels while considering time allocations for the VDC tasks. According to our findings, different companies have different automation levels, for instance, automated bill of materials as stated by the MEP Manager versus quantities taken off from the 3D models mentioned by the Electrical-1 Manager and the Electrical-2 Manager. In these examples, the same task, i.e., generating a bill of materials (4.1.2 Material Specifications and Procurement), is automated, but the level of automation is variable. This difference in automation levels subsequently has a variable impact on the time spent on a particular task. Thus, people who seek to develop industry benchmarks and metrics should consider the levels of automation to allocate time proportionately to the tasks that leverage this automation.

Automation Through Customized Integration

The MEP industry can embed their authoring software for 3D models like Revit with specialized software packages like Stratus, Evolve, and DrawerAI as per their trade-oriented needs to get the specific and detailed information. Companies can integrate authoring software with in-house customized software development using coding and scripting languages. This integration would produce generalized output and specialized output and complement detailers',coordinators' and manager's work.

Automated Fabrication Support Tasks

The MEP industry can automate different tasks like preparing bills of materials, conducting procurement and ordering of parts, customization for interoperability, and integration of 3D models with off-the-shelf or in-house software technology. Automation can ultimately support fabrication and the overall delivery of projects.

Automating Repetitive Tasks

The MEP industry can automate repetitive tasks. We found that tasks that are repetitive can be automated. For instance, preparing sheets, plotting different views on sheets, and dimensioning. These repetitive tasks can be automated using coding, scripts, and specialized software. The industry can figure out repetitive tasks per their trade-specific work and can automate repetitive tasks to save time allocated to those tasks.

In-House Need-Based Development

The MEP industry can have in-house software developers to develop customized solutions for their particular needs. One interesting finding is that a company has in-house software development to develop tailored solutions according to their needs, like developing a complete tool palette, integrating systems by solving interoperability issues, and automating repetitive tasks. These solutions are all tailored to their specific needs.

Model-Based Workflow

The MEP industry can develop a model-based workflow to eliminate repetitive re-worknate redundancy. This model-based workflow urges companies to work as a team and develop information as a common shared data in the form of 3D models, moving from stage to stage, as mentioned by the MEP Manager, while adding on the necessary information per stage so that the data is accurate and gets detailed along the stages of work. This model-based workflow eliminates redoing work and thus reduces redundant work and subsequent time. Furthermore, information in the form of 3D models is accurate and detailed, and it is built on previous information, therefore there is no human error while regenerating the data again. Moreover, access to accurate data reduces communication gaps and requests for information. Therefore, model-based workflow would underpin an efficient way of working in various aspects.

Section 4: Tools for Creating National Benchmarking Metrics

In this section, we introduce the tools developed by our team to support the creation of benchmarking metrics. These tools are compatible with both Windows and macOS platforms and are designed to assist companies in evaluating their VDC performance through flexible, input-driven metrics. The first tool, TableTransformation, enables users to reformat raw data into a structure suitable for metric generation. The second tool, MetricsCreation, builds on this transformed data to produce final benchmark metrics tailored to the organization's needs. Building on this, we discuss the potential implications of these tools for industry, highlighting their potential to promote internal process improvement and enable standardized benchmarking across firms. Finally, we provide practical recommendations for implementation, ranging from creating company-specific benchmarks to contributing to an industry-wide benchmarking system, while also addressing the importance of data privacy and collaboration frameworks to ensure secure and meaningful data sharing.

Tools for Creating Metrics

We divide the metrics creation process into two main steps: table transformation and metrics creation. The first step involves cleaning and reformatting the raw data into a structure suitable for analysis. The second step focuses on visualizing the transformed data to gain more insights. To support and automate this workflow, we developed two Python-based tools, each aligned with one of the steps. This modular design offers users greater flexibility in exploring the data, while also keeping the tool architecture relatively easy and manageable.

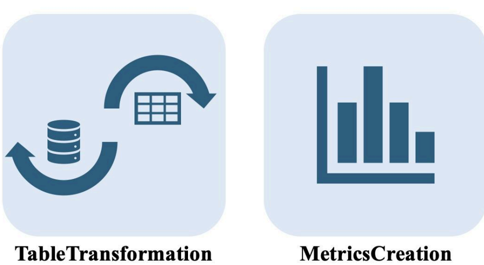

Figure 4-1. VDC Time Study Tools

To improve recognition, we named the tools based on their purposes as TableTransformation and MetricsCreation, and designed custom app icons for each, as shown in Figure 4-1. The tools and accompanying documentation have been published and are available for download at UW VDC Time Study Website (https://vdctime.be.uw.edu/).

(1) TableTransformation Tool

The TableTransformation process (illustrated in Figure 4-2) has been integrated into a single, user-friendly tool that streamlines data preparation and reduces manual effort. Users are only required to follow the step-by-step instructions provided in the documentation and format their data accordingly.

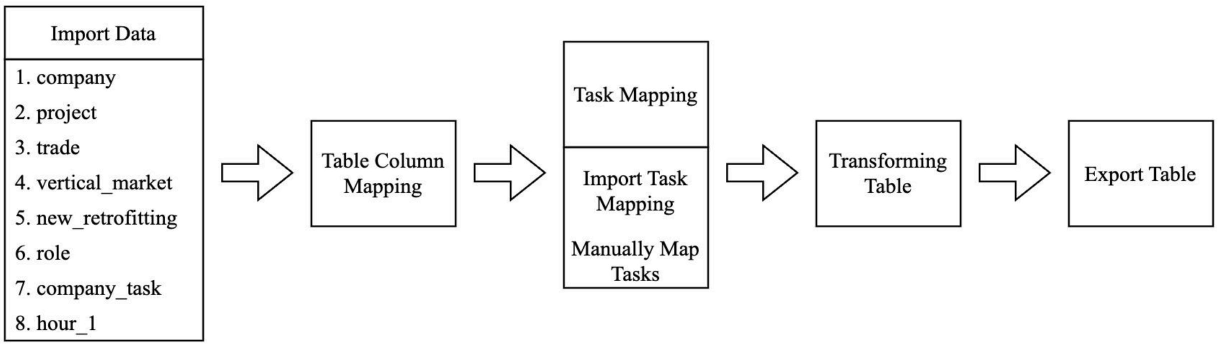

Figure 4-2. Table Transformation Workflow

In our initial exploration, the dataset we collected included information at the company, project, and employee levels. This rich data allowed us to examine potential factors influencing the time spent on various VDC activities. Based on our analysis, we identified and retained seven key variables for metrics creation (excluding time): company name (used as an identifier or pseudonym), project (similarly to the company name), trade, vertical market, role, and company task. Table 6-1 provides explanations for each metric variable used in the tool, along with a list of items included under each variable.

Table 5-1. Metric Variable Definitions and Associated Items

Data Schema	Explanation	Available Options
company	Your company identifier	
project	Each project is assigned a unique project number or identifier for reference and tracking purposes.	
trade	It refers to the project's specialized work or services provided.	Arch Metals, Electrical, Mechanical, Fire Protection, Piping, Plumbing, Sheet Metal, BIM Support.
vertical_market	It refers to the project's specific industry or sector.	Commercial, Data Center, Government, Healthcare, Industrial, Higher Education, Life Sciences, K-12 Education.
new_retrofitting	This categorization identifies whether a project is a new construction or a retrofitting project.	New Construction, Retrofitting.

Data Schema	Explanation	Available Options
role	The employee's role who submitted this data.	VDC Manager, VDC Coordinator, VDC Detailer, VDC Specialist, VDC Engineer, VDC Technician,
company_task	This is the task name used for tracking VDC activities in your organization.	

During the data mapping process, we observed that some company-provided task descriptions did not align perfectly with a single category in our standardized task schema. Instead, they often mapped to multiple categories with different percentage allocations. To accommodate this complexity, we integrated a function to support custom task breakdown with percentages. The mapping only needs to be completed once, as users can export and reuse their mapping configuration in future sessions.

(2) Metrics Creation Tool

Users can now create metrics using the transformed data from the previous step and the MetricsCreation Tool. Prior to importing the data into the tool, users may filter and refine the dataset using Excel spreadsheets, whether focusing on a single project or a specific group of projects.

Figure 4-3 illustrates the workflow incorporated in the tool. While we acknowledge that the tool can be further improved in several areas, our current focus has been on ensuring core functionality and producing reliable output. Therefore, it is essential to follow the instructions provided in the user documentation carefully. Failing to follow these steps may result in errors or wrong metrics.

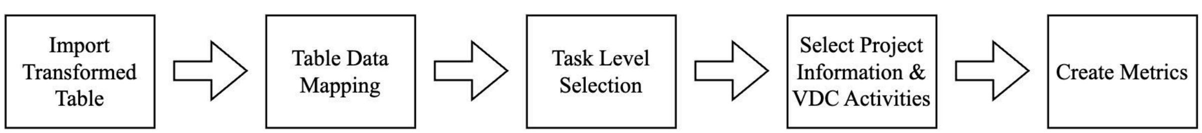

Figure 4-3. Metrics Creation Workflow

The Task Level section is where users determine the level of granularity at which they wish to analyze the data and generate metrics (see Figure 4-4). This step is based on the VDC Task Schema previously developed as part of this study. For more information on task level definitions and structure, refer to Section 1: VDC Task Schema Development.

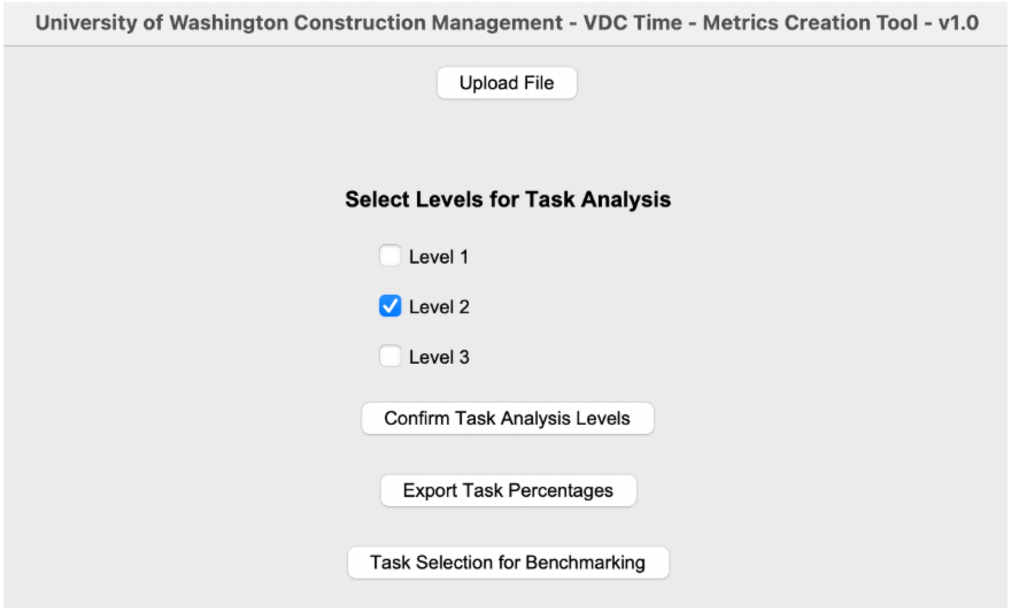

Figure 4-4. Task Level Selection

The final step before creating metrics is define your filter criteria. As shown in Figure 4-5, the window is divided into three sections:

1. Project information selection (left): Customize your metrics by focusing on specific trade, vertical market, new/retrofitting project, and role.

2. Activity/task selection in the selected level (middle): Generate metrics only for the selected tasks within the chosen task level, allowing for focused analysis tailored to your project or departmental needs.

3. Metrics (right): A box plot with jittered data points will be generated to visualize the distribution of the dataset and to extract basic statistical insights such as the mean, median, and quantiles. This approach helps reveal patterns, detect outliers, and support more interpretation of the data.

Figure 4-5. The Final Step for Creating Metrics

Tools for Creating National Benchmarking Metrics: Industry Implications

The creation of these tools provides a systematic approach to understanding how VDC departments operate and how time is allocated across various tasks. By enabling users to map, filter, and analyze time data through a consistent schema, the tools make it possible to visualize work distribution patterns across projects. This insight is particularly valuable for identifying time-intensive activities and supporting decision-making. An illustrative example of how the metrics are applied can be found in Appendix C.

Additionally, by allowing flexible task selection, the system accommodates the diverse roles and scopes of different companies, making the metrics more inclusive and representative of real-world conditions. This adaptability ensures that companies are not restricted by a one-size-fits-all model but can generate meaningful metrics tailored to their organizational needs.

In doing so, the tools not only promote internal evaluation and continuous improvement but also lay the foundation for broader industry benchmarking. When adopted across entire industries, they enable standardized comparisons that can inform best practices, resource allocations, and many more.

Tools for Creating National Benchmarking Metrics: Practical Recommendations

To drive the industry toward more efficient and data-informed practices, the development of a benchmarking system is essential. The following section outlines key recommendations for how industry professionals can apply and expand the use of this tool to support continuous improvement and informed decision-making.

(1) Create Company Benchmark

Organizations are encouraged to use the toolset to establish an internal benchmark. By analyzing time allocation across tasks within completed or ongoing projects, companies can gain a better understanding of their current performance. This baseline can serve as a reference point for evaluating future projects, identifying inefficiencies, and tracking the effectiveness of process improvements over time. Regularly updating the benchmark with new project data will also allow companies to monitor trends and guide long-term strategy in resource planning and training.

(2) Benchmark On-going Project

The toolset can be applied dynamically during live projects to monitor real-time performance. By comparing ongoing project time data against internal benchmarks or project targets, project managers can detect potential deviations early, enabling timely interventions.

(3) Industry-wide Benchmarking System

For broader impact, organizations are encouraged to participate in the development of an industry-wide benchmarking system. By contributing data through a shared framework, companies can help build a database of VDC activity metrics.

However, sharing project data across organizations can be challenging, particularly when such data may contain information related to productivity, performance, or cost. To address this concern, it is important to develop a data-sharing framework or protocol that enables organizations to contribute data in a secure and anonymized manner. In addition, this framework should be managed by a trusted industry body or association responsible for maintaining benchmarking datasets. Establishing clear guidelines on data confidentiality and usage will help build trust and encourage broader participation in industry-wide benchmarking efforts.

Future Directions

This report was designed to address the growing need for standardized benchmarking in VDC practices across the construction industry. Through collaboration with industry associations and their member companies, we developed a foundational task schema, analyzed time-tracking data, and identified early trends in task-role-responsibilities and automation in fabrication. Our findings and contributions provide an important starting point for construction companies seeking to understand how VDC work is structured and how performance can be assessed across projects. The schema and data model offer a baseline for organizations to evaluate their internal practices and align with broader industry efforts.

While this work establishes a strong foundation, achieving national benchmarking metrics will require ongoing coordination, sustained data-sharing, and iterative refinement. Continued engagement between academia and industry will be key to scaling this effort and unlocking the full potential of VDC-driven project delivery. Additional future efforts should focus on the following areas:

- Continue refining the VDC Task Schema by incorporating additional task categories, clarifying task definitions, and expanding descriptions to reflect emerging practices and industry feedback. As VDC workflows evolve and new technologies are adopted, it is essential to revisit and update the schema regularly to ensure it remains relevant, comprehensive, and usable across various organizational structures. This includes identifying specialized tasks that may not have been captured in the initial framework and providing clearer guidance on task boundaries. Establishing a feedback loop with industry practitioners can help validate these additions and ensure the schema accurately reflects real-world VDC operations.

- Incorporate and expand Task-Role-Responsibility mapping with the additional tasks, roles undertaking those tasks and their associated responsibilities. The additional tasks should be expanded in conjunction with roles (who undertakes those additional tasks) and responsibilities (what actions to be undertaken) to keep the Task-Role-Responsibility mapping up-to-date. This updated mapping will help improve time allocation for the VDC tasks. Additionally, this up-to-date mapping and improved time allocation subsequently supports the formulation of national benchmarking metrics for the VDC MEP industry.

- Assess the level of automation in the VDC workflow. The industry should assess their current level of automation in their VDC workflows and adjust time allocation to VDC tasks in view of the level of automation. The present level of automation can be improved by automating repetitive tasks in the VDC workflow and eventually adopting model based workflow. There is an opportunity for the MEP industry to solve industry specific pressing problems by using customized in-house/off-the-shelf technology.

- Develop a standardized data-sharing protocol that ensures consistency in data formats, sharing processes, and access controls, while addressing data privacy and security concerns. To facilitate broader industry participation in benchmarking efforts, it is important to build trust around data handling. This includes implementing anonymization practices, defining clear ownership and usage rights, and adopting secure data storage and transmission methods. Establishing transparent governance policies and offering legal or contractual frameworks such as data use agreements can further reduce hesitation and encourage collaboration across firms.

- Developing a national benchmarking system is a complex task. The factors considered in our study represent important early contributions, but they only address part of the broader challenge. Achieving a complete and reliable benchmarking framework will require further exploration of additional variables that also shape VDC performance. Continued research and industry input will be essential to fully capture the complexity of real-world implementation.

Endnotes

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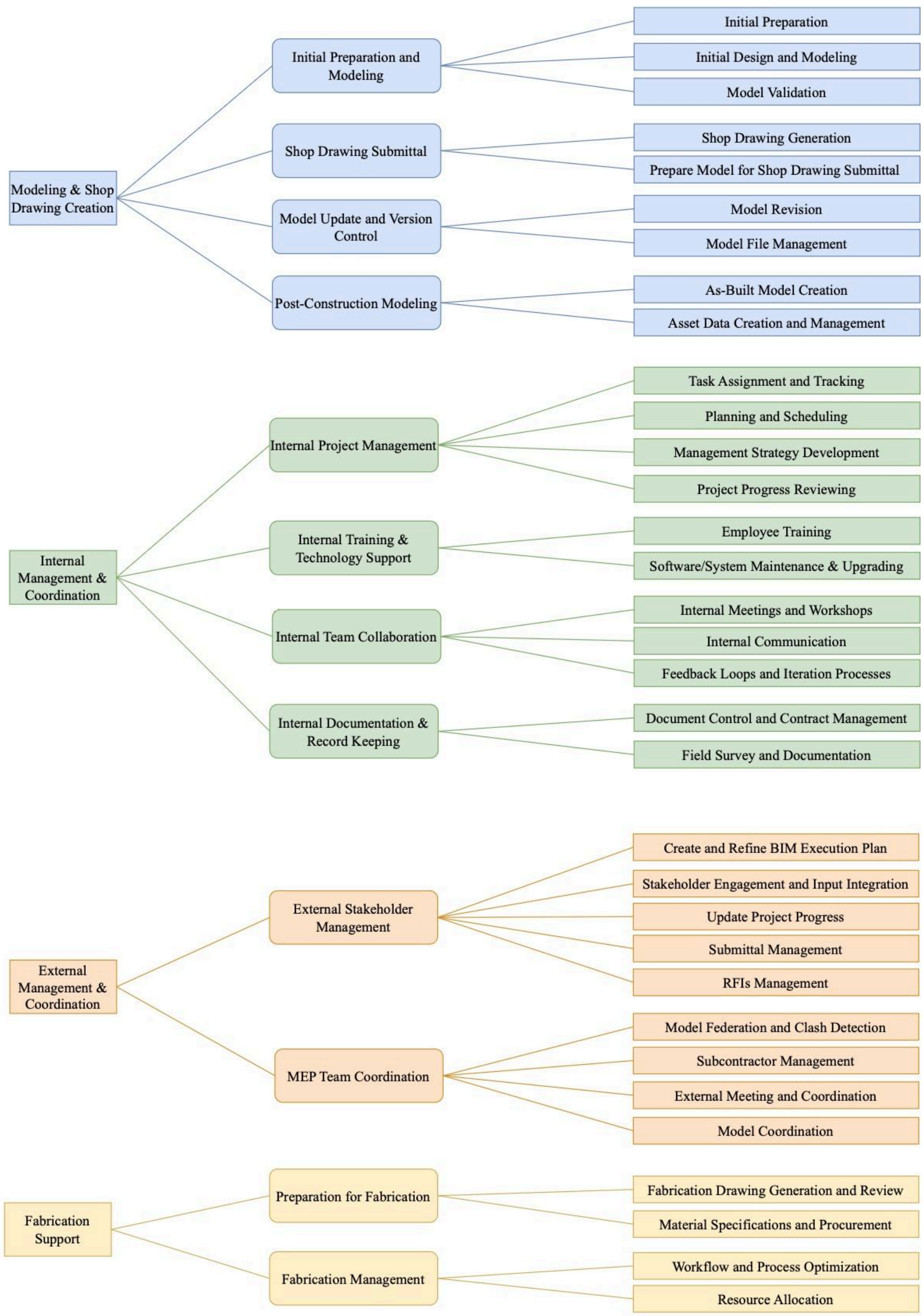
Appendices

Appendix A: VDC Activity Task Schema



Appendix B: Task-Role-Responsibility Analysis

Appendix B presents detailed analysis of the Figure 3-1 Task-Role-Responsibility mapping for roles (detailer, manager and coordinator), MEP trades (Electrical, Mechanical, Plumbing and Piping), experience (1-5, 5-10 and 10+ years) and VDC department versus Executive Management. The overall findings, as mentioned in the Section 2 are that roles of detailer and manager appear closely aligned, whereas the role of coordinator functions more as a standalone. Detailer performing tasks for Modeling and Shop Drawing Creation shows consistency across the industry, while Internal and External Management demonstrate greater variability. Managers typically perform or oversee tasks, whereas coordinators are mainly performing or consulted. Section B.1.0 Task-Role-Responsibility Mapping deals with roles and responsibilities in greater detail. Analysis of Task-Role-Responsibility mapping in conjunction with MEP trades exhibit no clear patterns that distinct one trade from the other MEP trades. Intricate details related to the MEP trades are given in Section B.2.0 Task-Role-Responsibility Mapping vs Trades. Notably, perceptions of Task-Role-Responsibility mapping differ between professionals with more experience (10+) and those with less experience (1–5 and 5–10 years) (refer to Section B.3.0 Task-Role-Responsibility Mapping vs Experience). Overall, the VDC department and Executive Management share a similar understanding, with some variations (refer to Section B.4.0 Task-Role-Responsibility Mapping for VDC Department and Executive Management).

B.1 Task-Role-Responsibility Mapping

The Figure 3-1 presents Tasks-Role-Responsibility mapping that builds on the Section-1 that introduced the VDC Task Schema. The mapping exhibits responsibilities (perform, consulted, and oversee) in percentage on y-axis as a 100% stacked column versus tasks being done in VDC of MEP industry on x-axis for three distinct roles (BIM/VDC coordinator, BIM/VDC detailer and BIM/VDC manager). It also illustrates 'not applicable' tasks for particular roles. Figure 3-1 offers a current landscape of working practices in VDC of MEP industry, exhibiting trends of responsibilities per task per role, whereas it also exhibits variety across the industry regarding responsibilities versus tasks for these roles. A survey was conducted at the MEP Innovation Conference 2025 that attracts MEP professionals in the US. These industry professionals had 1-10+ years of MEP industry experience. Industry professionals took part in the survey (156 responses) but 66 responses were finalized based on the percentage completion of response (having 77% and above) for the analysis and results.

B.1.1 BIM/VDC Detailer

Based on the survey respondents detailers follows a strong pattern of performance in 'Modeling & Shop Drawing Creation' but becomes increasingly variable in later tasks for 'Internal Management & Coordination', 'External Management & Coordination' and 'Fabrication Support'. At 'Modeling & Shop Drawing Creation', detailers predominantly perform the tasks assigned, indicating strong executional responsibility. This is complemented by a clear supervisory role from the manager particularly for ‘Modeling & Shop Drawing Creation’ tasks (1.1.1 to 1.4.2). For instance, all the ‘Modeling & Shop Drawing Creation’ tasks for detailers exhibit 62% (task 1.3.2 Model File Management) or greater percentage, as high as 91% (task 1.2.2 Prepare Model for Shop Drawing Submittal).

However, this pattern does not hold for ‘Internal Management & Coordination’ tasks (2.1.1 to 2.4.2). Here, the detailer's role shifts away from performance, showing a substantial decline in performing responses across all tasks as low as 9% (2.1.3 Management Strategy Development, 2.2.1 Employee Training), and the highest 55% for the task 2.3.2 Internal Communication. It is worthy to note that for ‘Internal Management & Coordination’ tasks, detailers’ applicable responsibilities are categorized between ‘performs’ and ‘consulted’, whereas ‘not applicable’ is also specified for the detailer as low as 20% (2.3.2 Internal Communication) to as high as 60% (tasks 2.1.3 Management Strategy Development and 2.2.2 Software/System Maintenance & Upgrading). This indicates a lack of consensus about the detailer’s involvement in Internal Management & Coordination tasks (2.1.1 to 2.4.2).

At ‘External Management & Coordination’, the responsibilities diversify between performing and consulting. The detailer is consulted on tasks like 3.1.1 Create and Refine the BIM Execution Plan (76%) and 3.1.2 Stakeholder Engagement and Input Integration (72%), whereas tasks like 3.2.4 Model Coordination (70%) and 3.2.1 Model Federation and Clash Detection (57%) are performed by the detailer and overseen by the manager, reflecting a collaborative working model between detailer and manager. This mix shows that the detailer maintains a relevant role but often in a supporting or shared capacity rather than as the primary executor as for the ‘Modeling & Shop Drawing Creation’ tasks.

‘Fabrication Support’ tasks (4.1.1 to 4.2.2) highlight a continued trend of disengagement from tasks 4.1.1 Fabrication Drawing Generation and Review (70%) to 4.2.2 Resource Allocation (11%) in terms of the prime executor. For instance, in task 4.2.2 Resource Allocation, approximately 65% of respondents indicated that the task was not applicable to the detailer, a significant increase from earlier tasks like 4.1.1 Fabrication Drawing Generation and Review, where only 16% selected not applicable. This upward shift indicates that either the task falls outside the detailer’s scope or lacks clear definition within organizational structures.

B.1.2 BIM/VDC Manager

According to the survey results, the manager demonstrates a consistent and prominent oversight role across tasks, particularly at ‘Modeling & Shop Drawing Creation’, where a strong oversee trend (44% to 78%) indicates that the manager oversees nearly every task that is been done by the detailer. This aligns with a traditional supervisory model, where task execution is delegated while leadership maintains strategic control.

As tasks evolve across the different levels, the manager increasingly shifts from oversight to performance. At ‘Internal Management & Coordination’ (2.1.1 to 2.4.2), the manager performs tasks which is a transition from overseeing the tasks being performed by the detailer in ‘Modeling & Shop Drawing Creation’. For example, tasks that show reduced engagement from the detailer in level 2.0 correspond with higher performance responses from the manager, suggesting a redistribution of responsibilities.

For ‘Internal Management & Coordination’,‘External Management & Coordination’ (3.1.1 to 3.2.4) and ‘Fabrication Support’ (4.1.1 to 4.2.2), the manager becomes the primary performer for several tasks, such as 3.1.1 Create and Refine the BIM Execution Plan (63%), 3.1.2 Stakeholder Engagement and Input Integration (74%), 4.2.1 Workflow and Process Optimization (56%) and 4.2.2 Resource Allocation (50%), while still maintaining an oversight responsibility in others, such as 3.2.1 Model Federation and Clash Detection (60%), 3.2.4 Model Coordination (67%), 4.1.1 Fabrication Drawing Generation and Review (78%) and 4.1.2 Material Specifications and Procurement (67%).

B.1.3 BIM/VDC Coordinator

For ‘Modeling & Shop Drawing Creation’ tasks (1.1.1 to 1.4.2) coordinator is responsible for performing, being consulted and overseeing, such as 1.1.3 Model Validation and 1.4.2 Asset Data Creating and Management. For ‘Internal Management & Coordination’ and ‘External Management & Coordination’ tasks, coordinator’s responsibilities are mostly divided in between performing and consulting. For instance, in task 2.3.2 Internal Communication, 84% of respondents stated that the coordinator performs the task, while in task 2.1.3 Management Strategy Development, only 26% marked performs, and 68% selected consulted. Similar pattern is visible for ‘External Management & Coordination’ like tasks 3.1.4 Submittal Management, 3.2.4 Model Coordination. Such variation demonstrates the coordinator’s role on projects varies across the industry, perhaps in response to specific task needs, between perform and consulted, rather than driven by a fixed role definition.

But for ‘Fabrication Support’, a decline in performing responses becomes evident (Figure 3-1), while ‘not applicable’ steadily rises—from 15% in task 4.1.1 Fabrication Drawing Generation and Review to 55% in task 4.2.2 Resource Allocation. This may reflect diminishing clarity about the coordinator’s function for ‘Fabrication Support’ tasks, potentially due to overlaps with managerial or detailing functions. While the coordinator continues to contribute meaningfully in terms of performing and providing consulting, the ‘not applicable’ category signals the diminishing clarity that need for more defined boundaries and expectations for ‘Fabrication Support’ tasks.

B.2 Task-Role-Responsibility Mapping vs. Trade

The following graph presents Task-Role-Responsibility mapping based on trades. It is worth mentioning that this is the same data as shown in Figure 3-1 but parsed out based on MEP Trades. There are four different trades namely; Electrical (E), Mechanical (M), Plumbing (P) and Piping (Pi). As before, tasks of VDC MEP industry are outlined on x-axis and corresponding responsibilities (perform, consulted, oversee and not applicable) on y-axis. Furthermore, these are separated out based on each trade (E, M, P and Pi) for each role (coordinator, detailer and manager). Figures B-1 to B-4 are representative of 'Modeling & Shop Drawing Creation' (1.1.1 to 1.4.2), 'Internal Management & Coordination' (2.1.1 to 2.4.2), 'External Management & Coordination' (3.1.1 to 3.2.4), and 'Fabrication Support' (4.1.1 to 4.2.2) respectively.

1.1.1 Initial Preparation	1.1.2 Initial Design & Modelling	1.1.3 Model Validation	1.2.1 Shop Drawing Generation
1.2.2 Prepare Model for Shop Drawing Submittal	1.3.1 Model Revision	1.3.2 Model File Management	1.4.1 As-built model creation
1.4.2 Asset Data Creating and Management			

Figure B-1. Task-Role-Responsibility Mapping vs Trade for 'Modeling & Shop Drawing Creation' Tasks

For 'Modeling & Shop Drawing Creation' tasks (1.1.1 to 1.4.2), the role of 'coordinator' exhibits all three responsibilities (performs, consulted and overseen) but the predominant responsibility is performance ranging from 70% (1.1.3 Model Validation) to 42% (1.4.2 Asset Data Creating and Management). Bifurcation of responsibilities per trade (Electrical, Mechanical, Plumbing and Piping) also showed the same pattern with Electrical trade being on the higher end for performance, whereas Plumbing and Mechanical showed some low values. For instance, Electrical trade shows a stronger trend for 'performs' 64.7% as compared to 60% for 1.1.1 Initial Preparation, 76.5% as compared to 70% for 1.1.3 Model Validation, and 70.6% as compared to 58% for 1.3.2 Model File Management. On the other hand, Plumbing shows a lower trend like 60.7% as compared to 70% for 1.1.3 Model Validation, 45.8% as compared to 57% for 1.2.2 Prepare Model for Shop Drawing Submittal, and 38.5% as compared to 53% for 1.3.1 Model Revision. Also, Mechanical shows a lower trend in ‘performs’ for the last three tasks (1.3.2 Model File Management, 1.4.1 As-built model creation and 1.4.2 Asset Data Creating and Management) and subsequent higher value for ‘consulted’.

All the trades, Electrical, Mechanical, Plumbing and Piping for ‘Modeling & Shop Drawing Creation’ tasks for the role of ‘detailer’ showed all three responsibilities (performs, consulted and oversees) as shown in the Figure 3-1 Task-Role-Responsibility. But the predominant trend is ‘performs’ for the detailer across all trades. Piping trade shows a slightly higher trend as compared to the Figure 3-1 Task-Role-Responsibility mapping. Furthermore, Electrical, Mechanical and Plumbing trades represented lower percentages to perform task 1.3.2 Model File Management (62%), which are 52.9%, 56% and 60% respectively and exhibit an increase in consulted responsibility. Also, Mechanical, Plumbing and Piping show lower values for task 1.4.2 Asset Data Creating and Management (63%) with 46%, 50% and 50% and the highest values for ‘consulted’ for level 1.0 tasks as compared to Figure 3-1 Task-Role-Responsibility mapping.

For the role of manager for the ‘Modeling & Shop Drawing Creation’ tasks, when it comes to trades like Electrical, Mechanical, Plumbing and Piping, all trades represent all three responsibilities (performs, consulted and overseen) but the predominant responsibility of manager is ‘overseen’. However, for tasks 1.3.2 Model File Management and 1.4.2 Asset Data Creating and Management all MEP trades show lower values for ‘overseeing’ and higher values for ‘performs’.

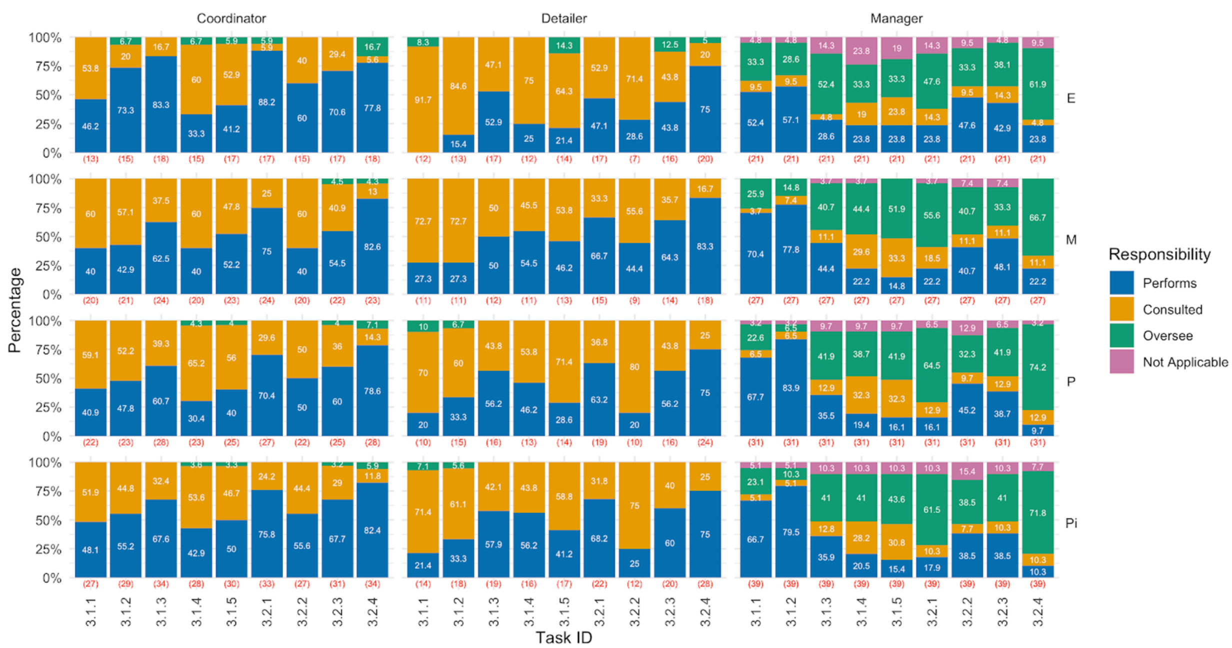
2.1.1. Task Assignment and Tracking	2.1.2 Planning and Scheduling	2.1.3 Management Strategy Development	2.1.4 Project Progress Reviewing
2.2.1 Employee Training	2.2.2 Software/System Maintenance & Upgrading	2.3.1 Meetings and Workshops	2.3.2 Internal Communication
2.3.3 Feedback Loops and Iteration Processes	2.4.1 Document Control and Contract Management	2.4.2 Field Survey and Documentation	

Figure B-2. Task-Role-Responsibility Mapping vs Trade for 'Internal Management & Coordination' Tasks

For 'Internal Management & Coordination', all three responsibilities are acknowledged for 'coordinator', with a split between 'performs' and 'consulted' and 'oversees' is negligible. Electrical (2.3.1 Internal Meetings and Workshops, 2.3.2 Internal Communication, and 2.3.3 Feedback Loops and Iteration Processes) and Mechanical trades (2.1.1 to 2.2.2) represented higher values for particular tasks. Plumbing trade exhibits the lowest values for all tasks (2.1.1 to 2.4.2). As there is a split between 'performs' and 'consulted' for 'Internal Management & Coordination' tasks rather than a dominating trend, some tasks that showed lower value for 'performs' have higher values for 'consulted' as compared to the mean values in Figure 3-1 Task-Role-Responsibility mapping. For example, task 2.2.1 Employee Training (31% and 66%) shows variability for Electrical (14.3% and 78.6%) and Plumbing (14.3% and 85.7%); task 2.3.3 Feedback Loops and Iteration Processes (55% and 43%) shows variability for Mechanical (47.4%, 52.6%), Plumbing (36.4% and 63.6%) and Piping (48.1% and 51.9%); task 2.4.1 Document Control and Contract Management (57% and 42%) has deviation for Electrical (53.8% and 46.2%), Mechanical (52.4% and 57.6%), Plumbing (45.8% and 54.2%) and Piping (53.6% and 46.4%); and task 2.4.2 (50% and 44%) has deviation for Electrical (25% and 58.3%), Plumbing (38.1% and 61.9%) and Piping (50% and 50%).

For ‘Internal Management & Coordination’ tasks for ‘detailers’, two responsibilities ‘perform’ and ‘consulted’ are exhibited, but there is a strong ‘not applicable’ trend for the role of detailer for these tasks as well. Electrical trade represented the lowest values for ‘not applicable’ whereas higher values for ‘consulted’ and ‘performance’ (2.3.1 Internal Meetings and Workshops, 2.3.2 Internal Communication). On the other hand, Mechanical and Plumbing showed a strong trend for ‘not applicable’ for the role of detailer.

For ‘Internal Management & Coordination’ tasks there is a strong trend for ‘performance’ of work by the ‘manager’ followed by ‘oversee’. Also, there are slight ‘consulted’ and ‘not applicable’ patterns too. Electrical trade exhibits a strong pattern for ‘perform’ as compared to ‘oversee’. On the other hand, Mechanical, Plumbing and Piping have strong patterns for performance but also have consulted, oversee and not applicable too. It is noteworthy that task 2.4.2 Field Survey and Documentation has the most variability that all four elements: perform, consulted, oversee, as well as not applicable are opted for this activity and having different values for each trade.



3.1.1 Create and Refine the BIM Execution Plan	3.1.2 Gathering Feedback and Concerns	3.1.3 Update Project Progress	3.1.4 Submittal management
3.1.5 RFIs management	3.2.1 Model Federation and Clash Detection	3.2.2 Subcontractor Management	3.2.3 External Meeting and Workshop
3.2.4 Model Coordination			

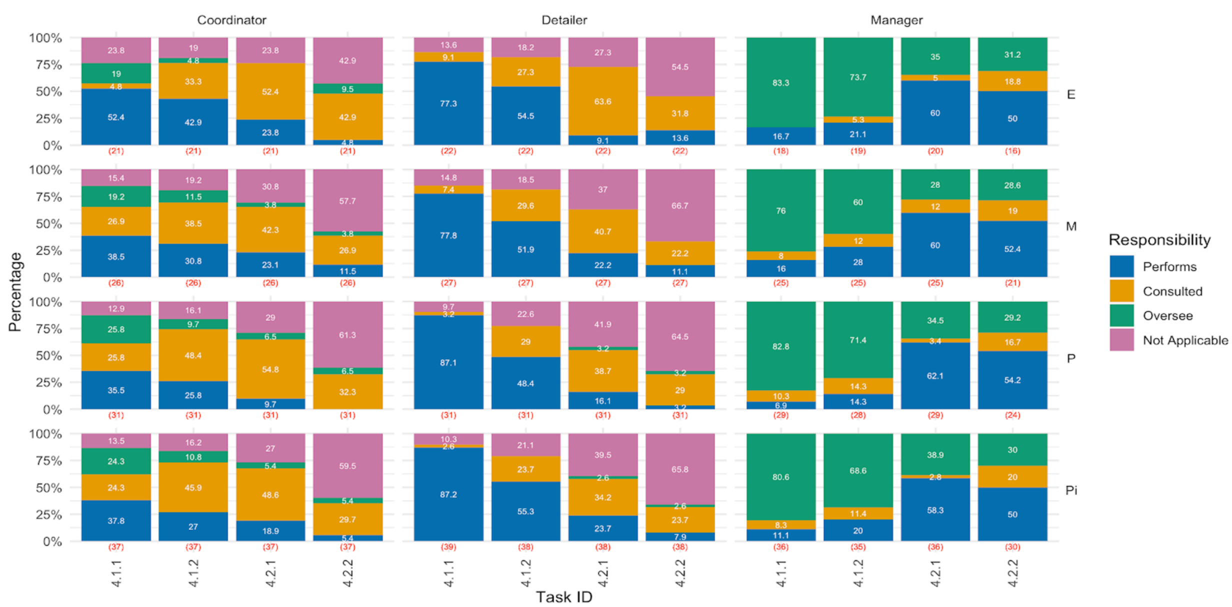
Figure B-3. Task-Role-Responsibility Mapping vs Trade for ‘External Management & Coordination’ Tasks

For the ‘External Management & Coordination’ tasks for ‘coordinator’, Electrical trade shows slightly higher values for ‘perform’ like, 3.1.2 Stakeholder Engagement and Input Integration

(73.3%), 3.1.3 Update Project Progress (83.3%) and 3.2.1 Model Federation and Clash Detection (88.2%), whereas Mechanical and Plumbing present slightly higher values for ‘consulted’ like 3.1.1 Create and Refine BIM Execution Plan (60%) for Mechanical and 3.1.4 Submittal Management (65.2%) for Plumbing have the highest values.

In the case of ‘External Management & Coordination’ tasks for the role of ‘detailer’, trades present slight variations for ‘perform’ and ‘consulted’ but there is no predominating difference. Electrical shows slightly higher values for the ‘consulted’ like 3.1.1 Create and Refine the BIM Execution Plan (91.7%), 3.1.2 Stakeholder Engagement and Input Integration (84.6%), and 3.1.4 Submittal Management (75%).

For ‘External Management & Coordination’ tasks for ‘manager’, all trades represented higher values for ‘perform’ for the tasks 3.1.1 Create and Refine the BIM Execution Plan and 3.1.2 Stakeholder Engagement and Input Integration but Mechanical and Plumbing showed the highest values for the performance, such as 70.4% and 83.9% respectively. On the other hand, all trades exhibit higher values for ‘oversee’ for tasks 3.2.1 Model Federation and Clash Detection and 3.2.4 Model Coordination but Plumbing has the highest values, such as 64.5% and 74.2% respectively. It is noteworthy that Electrical reveals slightly higher values for ‘not applicable’ as compared to other three trades, such as 14.3% for 3.1.3 Update Project Progress, 23.8% for 3.1.4 Submittal Management and 19% for 3.1.5 RFIs Management.



4.1.1 Fabrication Drawing Generation and Review	4.1.2 Material Specifications and Procurement	4.2.1 Workflow and Process Optimization	4.2.2 Resource Allocation

Figure B-4. Task-Role-Responsibility Mapping vs Trade for ‘Fabrication Support’ Tasks

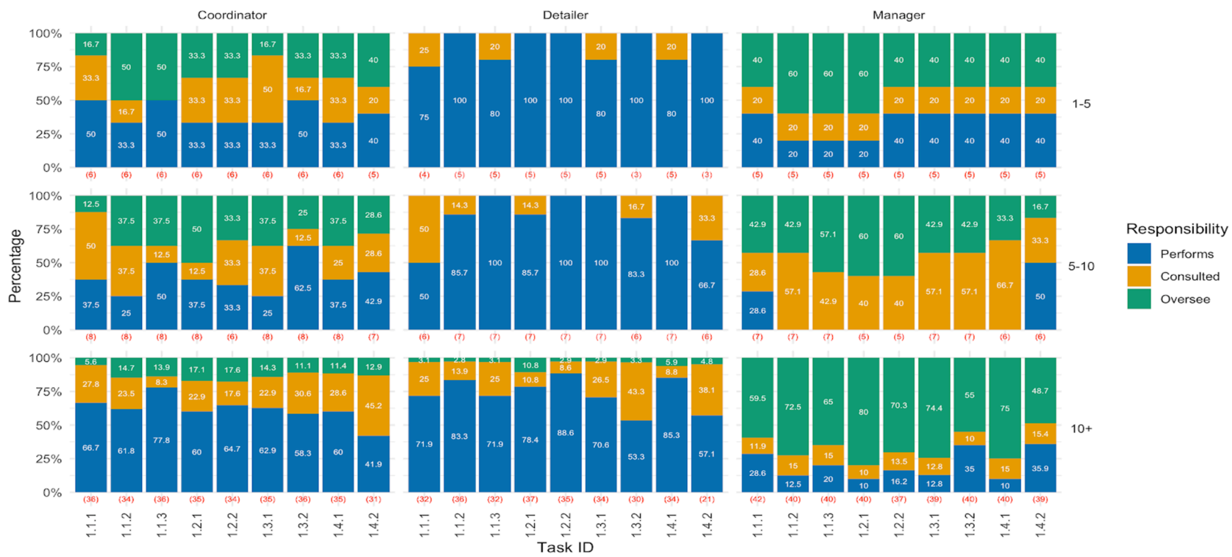
For ‘Fabrication Support’ tasks for ‘coordinator’, there is no clear trend for a single responsibility and that is also presented by all trades. Electrical trade reveals the highest value for tasks 4.1.1 Fabrication Drawing Generation and Review and 4.1.2 Material Specifications and Procurement, Plumbing trade reports the highest values for ‘consulted’ for tasks 4.1.2 Material Specifications and Procurement and 4.2.1 Workflow and Process Optimization, and for ‘not applicable’ for 4.2.2 Resource Allocation.

For the ‘Fabrication Support’ tasks, pattern of responsibilities distribution for ‘detailer’ is more or less similar for all trades with slight differences. The pattern is that ‘perform’ is consistently decreasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation for all trades having the highest values for Plumbing and Piping and lowest values for Electrical and Mechanical, ‘consulted’ increased from 4.1.2 Material Specifications and Procurement to 4.2.1 Workflow and Process Optimization, and ‘not applicable’ is consistently increasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation for all trades having the highest value for Mechanical and the least value for Electrical.

For ‘Fabrication Support’ tasks, all trades display the same trend overarchingly for ‘manager’ role, which is an increase in ‘perform’ from 4.1.1 Fabrication Drawing Generation and Review to 4.2.1 Workflow and Process Optimization tasks and a slight decrease for 4.2.2 Resource Allocation, a consistent decrease in ‘oversee’ from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation tasks. It is worth noting that Plumbing showed the lowest values for ‘perform’ for tasks 4.1.1 Fabrication Drawing Generation and Review and 4.1.2 Material Specifications and Procurement, whereas, it presents the highest values for tasks 4.2.1 Workflow and Process Optimization and 4.2.2 Resource Allocation. On the other hand, Electrical reveals the highest values for ‘oversee’ for tasks 4.1.1 Fabrication Drawing Generation and Review, 4.1.2 Material Specifications and Procurement, and 4.2.2 Resource Allocation.

B.3 Task-Role-Responsibility Mapping vs. Experience

Another variable we analyzed was the ‘experience’ level of the respondents, which is divided into 1-5, 5-10 and 10+ years of experience. The majority of the respondents have 10+ years of experience that can be seen from the data points given at the bottom of the bars in red font. Figures B-5 to B-8 exhibit the results for Task-Role-Responsibility for each role (coordinator, designer, manager) based on three different experiences.



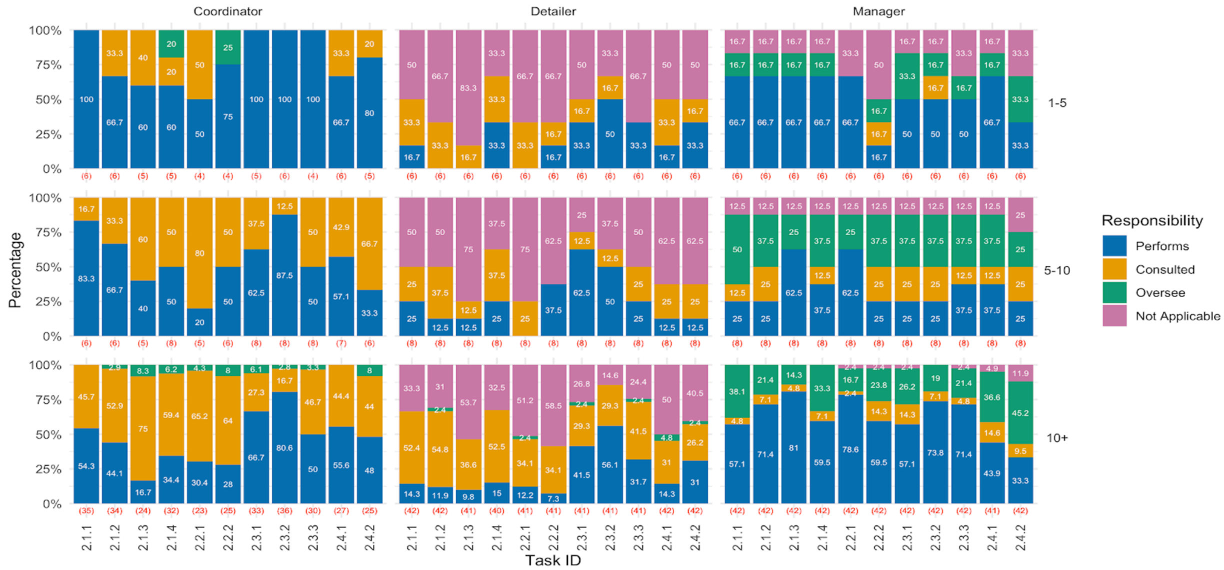
1.1.1 Initial Preparation	1.1.2 Initial Design & Modelling	1.1.3 Model Validation	1.2.1 Shop Drawing Generation
1.2.2 Prepare Model for Shop Drawing Submittal	1.3.1 Model Revision	1.3.2 Model File Management	1.4.1 As-built model creation
1.4.2 Asset Data Creating and Management			

Figure B-5. Task-Role-Responsibility Mapping vs Experience for 'Modeling & Shop Drawing Creation' Tasks

For 'Modeling & Shop Drawing Creation' tasks (1.1.1 to 1.4.2) the predominant trend for 'coordinator' is 'performs' then 'consulted' and subsequently 'oversees'. The same trend, even stronger, is exhibited by 10+ years of experience, whereas differences in trend for particular tasks can be seen for other two experience categories. For instance, tasks 1.1.1 Initial Preparation (60, 32, 08), 1.1.2 Initial Design & Modeling (52, 25, 23) 1.1.3 Model Validation (70, 08, 22) percentages for perform, consulted and oversee respectively, but these percentages are significantly varied for 1-5 and 5-10 years of experienced respondents as compared to 10+ years of experience and values of the Figure 3-1 Task-Role-Responsibility mapping.

For 'Modeling & Shop Drawing Creation' the predominant theme is 'performs' for the role of detailer. Same theme is presented by all levels of experience, an even stronger trend towards 'performing' tasks is exhibited by 1-5 and 5-10 years of experience as evident with 100% represented for numerous 'Modeling & Shop Drawing Creation' tasks. This indicates that there is confusion in understanding the job roles and subsequent responsibilities in the workforce.

For 'Modeling & Shop Drawing Creation' tasks for 'manager', the same trend is represented by 10+ years of experience when compared to the Figure 3-1 Task-Role-Responsibility mapping that is predominantly 'oversees'. But 1-5 years of experience, show a division between oversee and perform (tasks 1.2.2 Prepare Model for Shop Drawing Submittal to 1.4.2 Asset Data Creating and Management) and 5-10 years of experience don't even account for performance (tasks 1.1.2 Initial Design & Modeling to 1.4.1 As-built model creation) and represent a division between oversee and consulted without a clear dominating trend between the two responsibilities indicating a confusion about the roles and responsibilities for these tasks as a shared collective understanding.



2.1.1. Task Assignment and Tracking	2.1.2 Planning and Scheduling	2.1.3 Management Strategy Development	2.1.4 Project Progress Reviewing
2.2.1 Employee Training	2.2.2 Software/System Maintenance & Upgrading	2.3.1 Meetings and Workshops	2.3.2 Internal Communication
2.3.3 Feedback Loops and Iteration Processes	2.4.1 Document Control and Contract Management	2.4.2 Field Survey and Documentation	

Figure B-6. Task-Role-Responsibility Mapping vs Experience for 'Internal Management & Coordination' Tasks

For the 'Internal Management & Coordination' tasks for 'coordinator', all three responsibilities are exhibited in Figure 3-1 Task-Role-Responsibility mapping with a split between 'perform' and 'consulted' and a minor contribution of 'oversee'. Same trend can be generally seen from the three different years of experience. Nevertheless, it can be observed that the trend for 'perform' becomes stronger from 10+ to 1-5 years of experience, such as tasks 2.1.1 Task Assignment and Tracking, 2.3.1 Internal Meetings and Workshops, 2.3.2 Internal Communication and 2.3.3 Feedback Loops and Iteration Processes exhibit 100% for performance.

For 'Internal Management & Coordination' tasks related to the 'detailer' role, there is a split between applicability and non applicability of these tasks. The trend shows performances and consulted as one half, whereas 'not applicable' as another half. The variability is also evident in the years of experience, where the 'not applicable' trend is stronger from 10+ years of experience to 5-10 and 1-5 years of experience. On the other hand, 10+ years of experience represented higher values of 'consulted' as compared to 5-10 and 1-5 years of experience professionals.

For 'Internal Management & Coordination' tasks for 'manager', predominant trend is 'performs', then 'overseed', and minor proportion of consumed and not applicable. This trend is resonated by 10+years of experience, whereas variable trends are observed in 1-5 and 5-10 years of experience. For instance, tasks 2.2.2 Software/System Maintenance & Upgrading (9%) and 2.4.2 Field Survey and Documentation (16%) show higher for 'not applicable' values of 50% and 33.3% respectively, by 1-5 years of experience. On the other hand, 1-5 years of experience expressed higher values for 'oversee'.

3.1.1 Create and Refine the BIM Execution Plan	3.1.2 Gathering Feedback and Concerns	3.1.3 Update Project Progress	3.1.4 Submittal management
3.1.5 RFIs management	3.2.1 Model Federation and Clash Detection	3.2.2 Subcontractor Management	3.2.3 External Meeting and Workshop
3.2.4 Model Coordination			

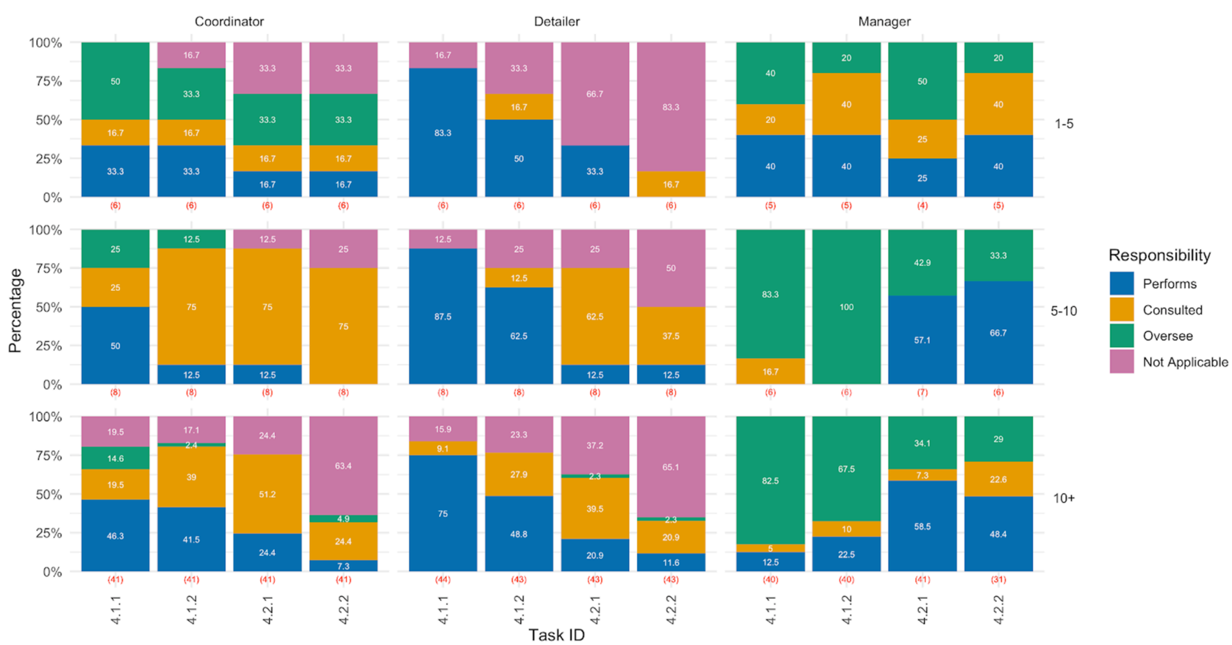
Figure B-7. Task-Role-Responsibility Mapping vs Experience for 'External Management & Coordination' Tasks

For 'External Management & Coordination' tasks for 'coordinator', the predominating 'perform' pattern is visible from more to less experienced professionals. Professionals having 10+ years of experience, also considered 'consulted' along with 'perform' responsibilities. Whereas, 5-10 and 1-5 years of experience are more inclined towards 'perform' with the trend getting stronger in favor of 'perform' for lesser years of experienced professionals. But task 3.2.2 Subcontractor Management showed the lower value for 'perform' as compared to usual trend exhibited by the 5-10 years of experience professionals.

For 'External Management & Coordination' tasks pertinent to the role of 'designer', experienced professionals like 10+ years of experience present a variable response between 'perform' and 'consulted' typically initial tasks like 3.1.1 Create and Refine the BIM Execution Plan (81%) and 3.1.2 Gathering Feedback and Concerns (79.2%) regarded 'consulted' as the main responsibility for the role of detailer and 'perform' for the tasks like 3.1.3 Update Project Progress (52%), 3.2.1

Model Federation and Clash Detection (50%) and 3.2.4 Model Coordination (71%). As noted earlier for other levels of tasks, the trend gets stronger for a particular responsibility. In this case, the dominating trend is to ‘perform’ from 1-5 to 5-10 years of experience. There is a split between ‘perform’ and ‘consulted’ for 1-5 years of experience professionals.

For ‘External Management & Coordination’ tasks, the results exhibit a split between ‘performs’ and ‘oversee’ by the ‘manager’, some contributions as ‘consulted’ and small percentages of ‘not applicability’. Similarly, 10+ years of experience resonate with the Figure 3-1 Task-Role-Responsibility mapping, and 1-5 years of experience also presented that pattern with a higher percentage of ‘not applicable’ i.e. 16.7% for all tasks. Whereas, 5-10 years of experience professionals reveal erratic patterns. For instance, lower values for ‘perform’ for tasks 3.1.1 Create and Refine the BIM Execution Plan, 3.1.3 Update Project Progress, 3.1.4 Submittal management and 3.2.3 External Meeting and Workshop; zero percentage for perform for 3.1.5 RFIs management, 3.2.1 Model Federation and Clash Detection and 3.2.4 tasks, higher percentages for ‘not applicable’ for 3.1.4 Submittal management, 3.1.5 RFIs management and 3.2.1 Model Federation and Clash Detection. The understanding of 5-10 years of professionals for the role of manager for level 3.0 tasks is erratic as compared to 1-5 and 10+ experience and cumulative mean values as shown in Figure 3-1 Task-Role-Responsibility mapping.



4.1.1 Fabrication Drawing Generation and Review	4.1.2 Material Specifications and Procurement	4.2.1 Workflow and Process Optimization	4.2.2 Resource Allocation

Figure B-8. Task-Role-Responsibility Mapping vs Experience for ‘Fabrication Support’ Tasks

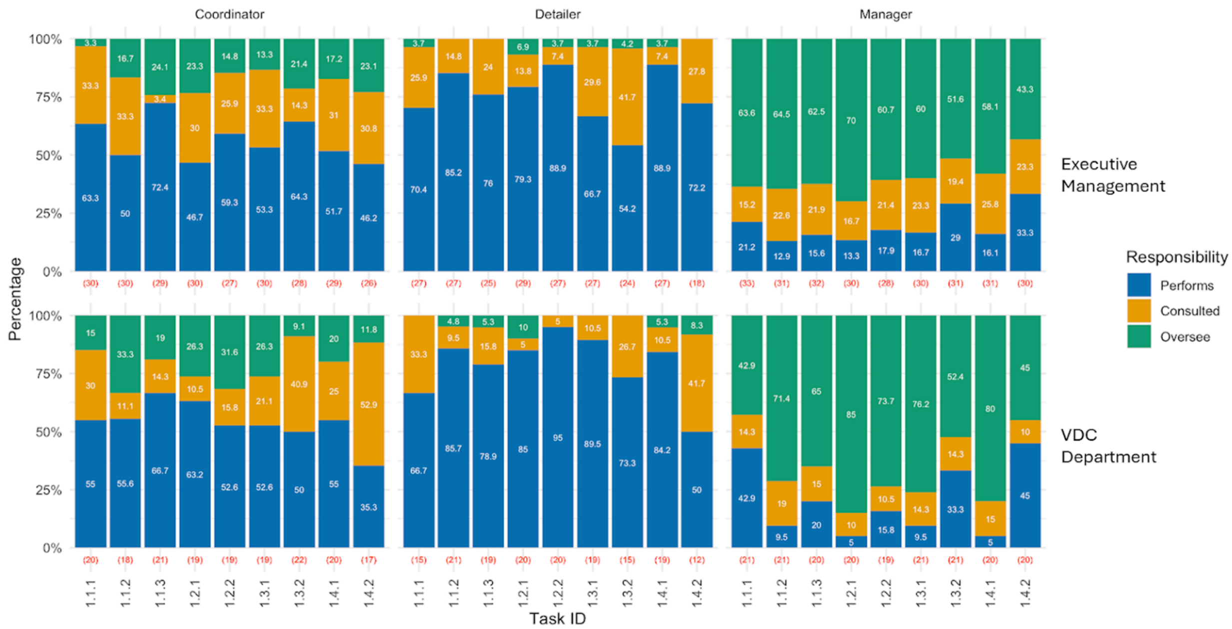
For ‘Fabrication Support’ tasks for the role of ‘coordinator’, experience levels report distinction in responsibilities being performed by coordinator. For instance, there is a clear difference among

5-10 years of experience with 1-5 and 10+, as it shows highest values for 'consulted' for 4.1.2 Material Specifications and Procurement, 4.2.1 Workflow and Process Optimization and 4.2.2 Resource Allocation. Professionals having 1-5 years of experience express the highest value for 'oversee' for 4.1.1 Fabrication Drawing Generation and Review, whereas, for 4.2.2 Resource Allocation 10+ state the highest percentage of 63.4% for 'not applicable' to the coordinator. There is a clear lack of shared understanding for these tasks by the industry professionals having varied working experience.

For 'Fabrication Support' tasks for the 'detailer' role, the overall trend is the same for all three different years of experience with some variability in terms of percentages for responsibilities. For example, 'perform' is consistently decreasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation, 'consulted' is increasing from 4.1.2 Material Specifications and Procurement to 4.2.1 Workflow and Process Optimization, whereas, 'not applicable' is consistently increasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation tasks. Professionals with 1-5 years of experience don't exhibit 'perform' for 4.2.2 Resource Allocation task, 'consulted' for 4.1.1 Fabrication Drawing Generation and Review and 4.2.1 Workflow and Process Optimization tasks, and reveal the highest value for 'not applicable' for 4.2.2 Resource Allocation task.

For 'Fabrication Support' tasks for 'manager', there are clear distinctions between the trend of 10+ years of experience as compared to 5-10 and 1-5 years of experience. For instance, there is no consistent increasing trend for 'perform' and consistent decreasing trend for ' oversee' from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation for both 1-5 and 5-10 years of experience; there is more like static values for 1-5 and 5-10 year of experience, like 40% for 'perform' for 4.1.1 Fabrication Drawing Generation and Review as compared to 14% for mean value from Figure 3-1 Task-Role-Responsibility mapping, and zero value for 'perform' for 4.1.1 Fabrication Drawing Generation and Review and 4.1.2 Material Specifications and Procurement and subsequent higher values for 'oversee'.

B.4 Task-Role-Responsibility Mapping for VDC Department and Executive Management :



1.1.1 Initial Preparation	1.1.2 Initial Design & Modelling	1.1.3 Model Validation	1.2.1 Shop Drawing Generation
1.2.2 Prepare Model for Shop Drawing Submittal	1.3.1 Model Revision	1.3.2 Model File Management	1.4.1 As-built model creation
1.4.2 Asset Data Creating and Management			

Figure B-9. Task-Role-Responsibility Mapping vs Executive Levels for 'Modeling & Shop Drawing Creation' Tasks

In the case of 'Modeling & Shop Drawing Creation' tasks pertinent to the role of 'coordinator', all three responsibilities (performs, consulted and overseen) are acknowledged to be done by the coordinator and the predominant responsibility is 'performs' and then 'consulted' and subsequently 'oversees'. But the percentage for performing responsibility is on conservative side by the VDC department as compared to the percentages exhibited by executive management. Additionally, VDC management shows higher values for 'oversee' responsibility as compared to executive management, whereas, executive management has shown more appreciation in values for 'consulted'. In a nutshell, although the predominant trend remains the same that is 'performs' for the role of coordinator for 'Modeling & Shop Drawing Creation' tasks, there is mismatch in the holistic comprehension of responsibilities being taken by the role of coordinator between VDC department and executive management. This leads to inaccurate expectations and demands from the executive management to the VDC management, thus a tug of war between the two to foresee the same vision together.

In the case of 'detailer' both levels of organization exhibit the same trend, which is predominantly detailer perform the tasks of 'Modeling & Shop Drawing Creation', then consulted and slightly overseen. But there is some variability between VDC Department and Executive Management for tasks 1.3.1 Model Revision, 1.3.2 Model File Management and 1.4.2 Asset Data Creating and Management.

VDC Department and executive management exhibit the same trend for ‘manager’, which is predominantly to oversee the ‘Modeling & Shop Drawing Creation’ tasks, and equally consult and perform for the role of manager. But there is some variability between VDC Department and Executive Management for tasks 1.1.1 Initial Preparation, 1.2.1 Shop Drawing Generation, 1.4.1 As-built model creation and 1.4.2 Asset Data Creating and Management.

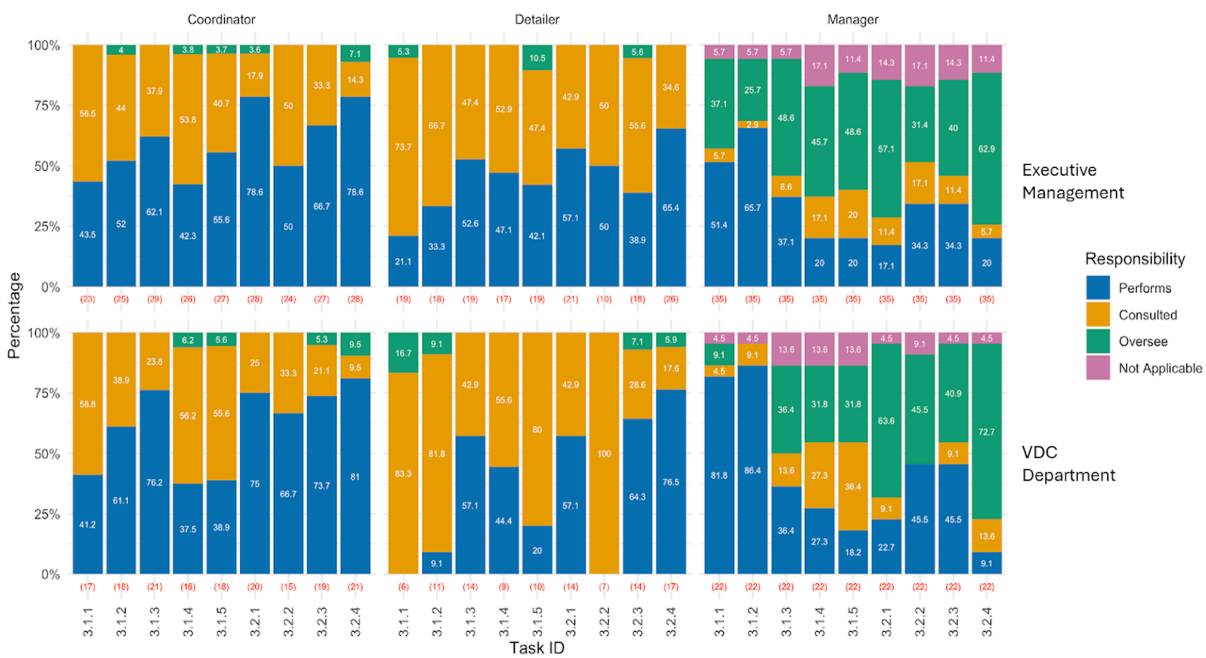
2.1.1. Task Assignment and Tracking	2.1.2 Planning and Scheduling	2.1.3 Management Strategy Development	2.1.4 Project Progress Reviewing
2.2.1 Employee Training	2.2.2 Software/System Maintenance & Upgrading	2.3.1 Meetings and Workshops	2.3.2 Internal Communication
2.3.3 Feedback Loops and Iteration Processes	2.4.1 Document Control and Contract Management	2.4.2 Field Survey and Documentation	

Figure B-10. Task-Role-Responsibility Mapping vs Executive Levels for ‘Internal Management & Coordination’ Tasks

For the ‘Internal Management & Coordination’ tasks for ‘coordinator’, there is variance between VDC department and executive management for ‘perform’ and ‘consulted’ as expressed in tasks 2.1.2 Planning and Scheduling, 2.1.3 Management Strategy Development, 2.2.1 Employee Training, 2.2.2 Software/System Maintenance & Upgrading, 2.3.1 Internal Meetings and Workshops and 2.3.2 Internal Communication. For example, VDC department professionals believe that coordinators are more involved in 2.3.1 Internal Meetings and Workshops (85%) and 2.3.2 Internal Communication (95%) as contrary to 57.7% and 76.7% by the executive management. Furthermore, for task 2.1.3 Management Strategy Development VDC department demonstrated 76.9% for ‘consulted’ but executive management expressed 61.9%.

For the ‘detailer’ role, there are some notable variations between the VDC department and executive management for the tasks 2.3.1 Internal Meetings and Workshops, 2.3.2 Internal Communication, 2.4.1 Document Control and Contract Management and 2.4.2 Field Survey and Documentation. For tasks 2.3.1 Internal Meetings and Workshops, 2.3.2 Internal Communication and 2.4.2 Field Survey and Documentation VDC department professionals expressed higher values for ‘perform’, but ‘not applicable’ for task 2.4.1 Document Control and Contract Management as opposed to executive management.

For ‘Internal Management & Coordination’ tasks, the main theme is ‘perform’, then ‘oversee’ and slight percentages of ‘consulted’ and ‘not applicable’. Both VDC and non-VDC professionals depict a more or less same trend for performance but non-VDC professionals exhibit higher values of ‘oversee’ for the tasks 2.4.1 Document Control and Contract Management and 2.4.2 Field Survey and Documentation. Also, both these tasks present perform, consulted, oversee and not applicable that also indicate variability for these two tasks for the role of manager.



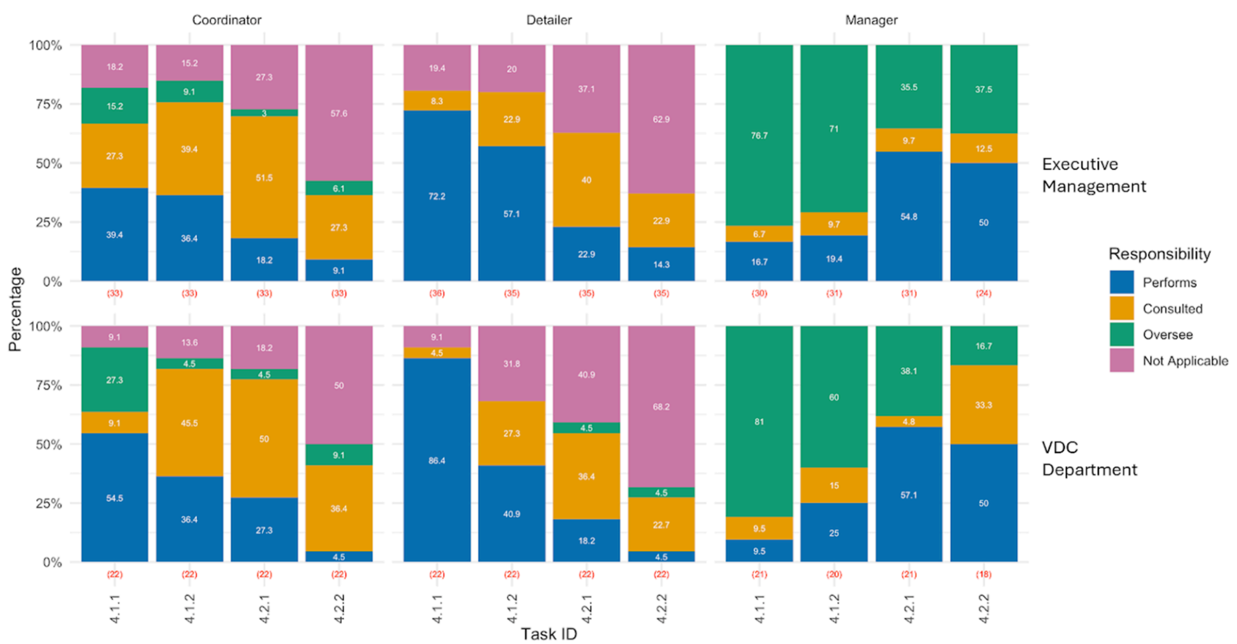
3.1.1 Create and Refine the BIM Execution Plan	3.1.2 Gathering Feedback and Concerns	3.1.3 Update Project Progress	3.1.4 Submittal management
3.1.5 RFIs management	3.2.1 Model Federation and Clash Detection	3.2.2 Subcontractor Management	3.2.3 External Meeting and Workshop
3.2.4 Model Coordination			

Figure B-11. Task-Role-Responsibility Mapping vs Executive Levels for ‘External Management & Coordination’ Tasks

For the ‘External Management & Coordination’ tasks for the role of ‘coordinator’, VDC department and executive management overarchingly have the same trend but VDC department have slightly higher ‘performance’ expectation and lower ‘consulted’ expectation for tasks 3.1.2 Stakeholder Engagement and Input Integration, 3.1.3 Update Project Progress, 3.1.5 RFIs Management and 3.2.2 Subcontractor Management tasks as compared to executive management.

For the ‘External Management & Coordination’ tasks for ‘detailer’, there is a complete disparity between executive management and the VDC department for the role of detailer for level 3.0 tasks. The VDC department paints an erratic picture with lower values for ‘perform’ such as tasks 3.1.2 Stakeholder Engagement and Input Integration and 3.1.5 RFIs Management, and higher values for ‘consulted’ 3.1.1 Create and Refine the BIM Execution Plan and 3.2.2 Subcontractor Management as compared to executive management.

For the ‘External Management & Coordination’ tasks regarding the role of ‘manager’, there are discrepancies between the VDC department and executive management for manager’s responsibilities. For instance, 3.1.1 Create and Refine the BIM Execution Plan and 3.1.2 Stakeholder Engagement and Input Integration represent higher ‘perform’ values, 3.1.5 RFIs management present higher values for ‘consulted’, 3.2.2 Subcontractor Management display higher values for ‘perform’ and ‘oversee’ with zero value for ‘consulted’, and 3.2.4 Model Coordination report lower value for ‘perform’ higher value for ‘consulted’ and ‘oversee’ as compared to executive management.



4.1.1 Fabrication Drawing Generation and Review	4.1.2 Material Specifications and Procurement	4.2.1 Workflow and Process Optimization	4.2.2 Resource Allocation

Figure B-12. Task-Role-Responsibility Mapping vs Executive Levels for Fabrication Support’ Tasks

For ‘Fabrication Support’ tasks for ‘coordinator’, both the VDC department and executive management report the same pattern (with slight variations) that ‘performance’ is consistently decreasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation tasks, ‘consulted’ is considerable for 4.1.2 Material Specifications and Procurement and 4.2.1 Workflow and Process Optimization, whereas ‘not applicable’ is consistently increasing from 4.1.1 Fabrication Drawing Generation and Review to 4.2.2 Resource Allocation tasks.

In the case of ‘detailer’ for the ‘Fabrication Support’ tasks, both the VDC department and executive management express the same trend with slight difference in percentage values.

For the ‘Fabrication Support’ tasks for ‘manager’, the same trend is revealed by both the VDC department and executive management with slight differences in the percentages.

Appendix C: Example of Benchmarking Metric Creation

In this section, we present an example to demonstrate how benchmarking metrics can be created using time-tracking data aligned with the VDC Task Schema (Section 1). This appendix walks through the key steps involved—from introducing the dataset and processing the raw inputs, to calculating task-based metrics, visualizing the results, and interpreting insights. The goal is to illustrate how this methodology can be applied in real-world settings to support internal performance evaluation and industry-wide benchmarking.

C.1 Introduction to the Example Dataset

The dataset used in this example to demonstrate the potential for developing national benchmarking metrics was obtained from a company participating in our VDC Time Study, which ran from September 2023 to June 2025. We offered two data contribution methods: (1) exporting time-tracking records from Clockify, primarily used by companies without an established time-tracking workflow; and (2) direct data sharing from companies with existing internal systems. As of the completion of this report, we have received data from over 300 projects, approximately one-third of which meet the criteria for further analysis.

After screening the dataset, we found that a significant portion of the data originated from a single company. We acknowledge that this imbalance may result in findings that are disproportionately influenced by that company's practices and workflows. As future efforts move toward establishing national benchmarking metrics, it may be necessary to apply weighting or normalization strategies to ensure more representative and balanced results across participating companies.

C.2 Step-by-Step Process for Creating Metrics

C.2.1 Data Preprocessing

Due to the current limitations of the tools we developed, the input data must meet certain requirements related to formatting (e.g., converting minutes to hours) and completeness (e.g., ensuring all required fields contain values). Detailed specifications are provided in the tool documentation available on our website. At this stage, each company's data was processed separately to support task mapping in the next step. All data processing was conducted using RStudio, a free and open-source data analysis software. The cleaned and formatted data was saved as *1. company_data_cc.xlsx*, where 1 indicates the processing step and cc represents the company-specific code.

C.2.2 Data Transformation

The primary goal of this step is to standardize each company's data to align with the formatting and schema requirements defined by our team. The first task involves mapping company-specific column names to the standard fields used in our tool (Figure C-1.). For instance, a column labeled worktype in a company's dataset might correspond to company_task in our standardized format. The second task is to map the company task to the task schema developed in our study. This process is essential for enabling consistent comparison across companies and lays the foundation for national benchmarking metrics.

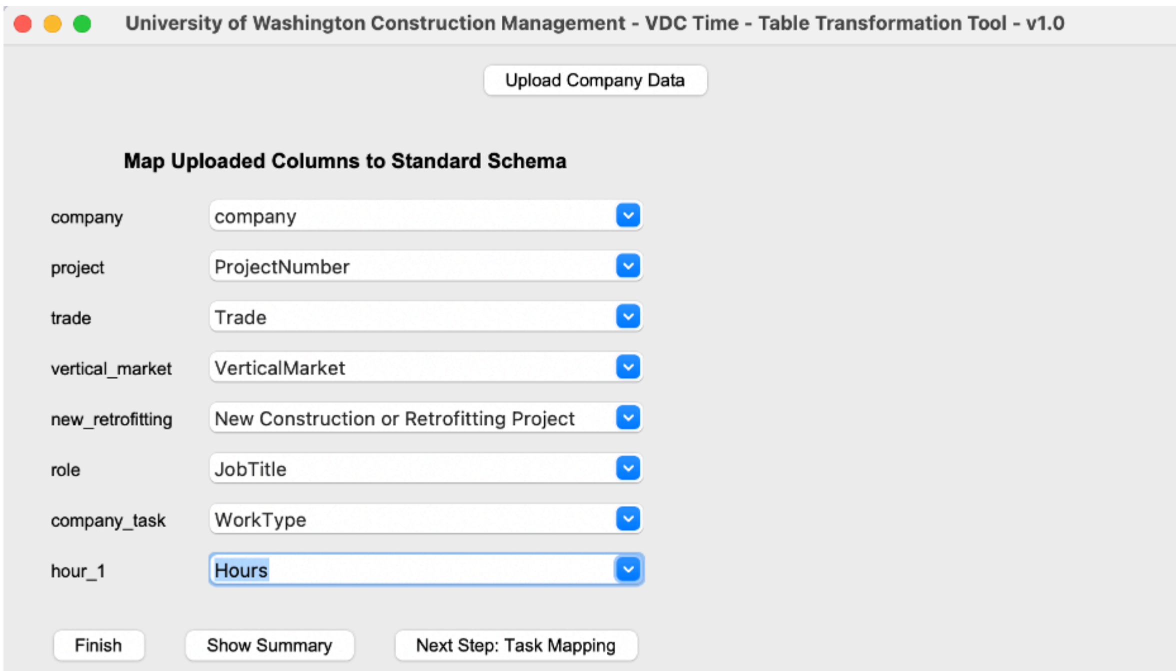


Figure C-1. Data Schema/Column Mapping

There are two options for completing the task mapping: manual mapping or importing a predefined mapping file. Since this was our first time mapping these tasks, we selected the manual option. This approach allowed us to match company tasks directly to the standardized task list. In cases where a single company task corresponded to multiple standardized tasks, we assigned percentage weights to reflect the distribution (Figure C-2). Once completed, the task mapping file was saved as *2. Task_mapping_cc.xlsx* and the data transformation process was initiated. Transformation might take a while depending on the volume of data.

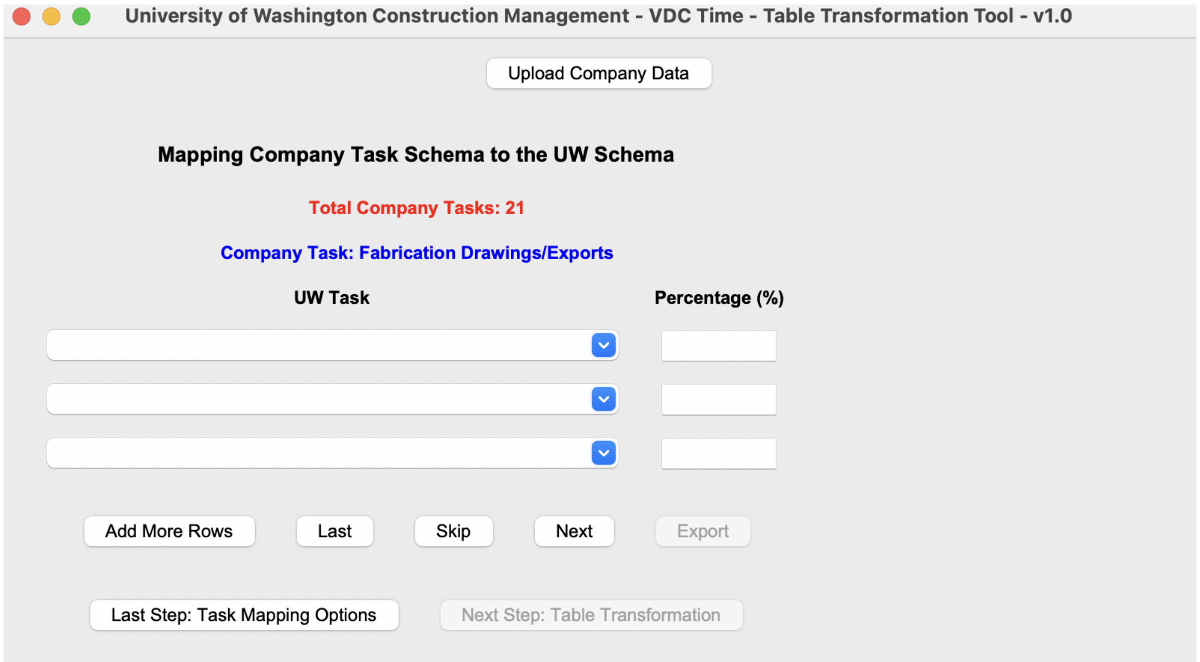


Figure C-2. Task Mapping

This process was repeated for each company, and the resulting files were saved as *3. transformed_table_cc.xlsx*. After all individual datasets were processed, we used RStudio to merge them into a single consolidated file named *3. transformed_table.xlsx*.

C.2.3 Metrics Creation

At this stage, we are one step away from generating benchmarking metrics. In the previous steps, both the data schema and VDC activity categories were standardized. However, the values within those fields still required additional cleaning to ensure consistency. To minimize errors, we further standardized field values by addressing issues such as inconsistent capitalization and naming conventions. For example, entries like “new/retrofitting” were reformatted to “new/retrofitting construction” for clarity and uniformity.

Once this cleanup was completed, the tool prompted us to select the level of activity for metric generation. For this analysis, we chose Level 2 activities. This selection led us to the final interface for benchmarking metrics creation (Figure C-3.).

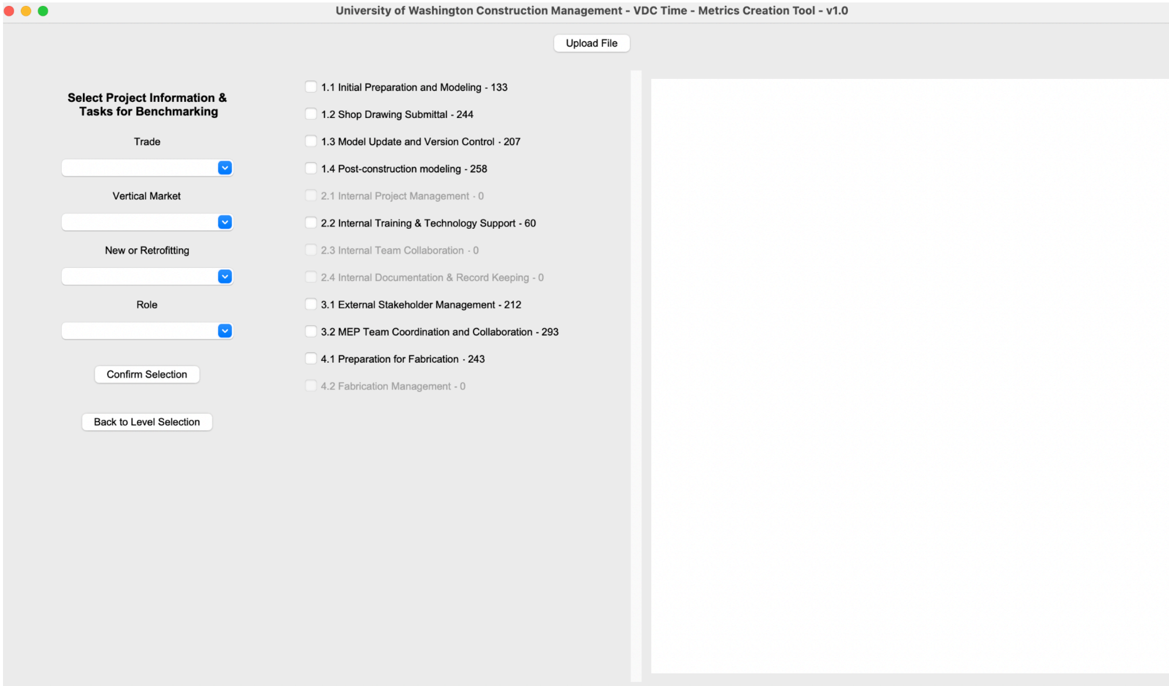


Figure C-3. Metrics Creation

C.3 Result and Discussion

In the following section, we present two examples to demonstrate the potential applicability of these benchmarking metrics. These cases highlight how the customized metrics can be used to support decision-making, identify performance gaps, and promote continuous improvement across projects.

C.3.1 Benchmarking for VDC Detailers: Modeling and Shop Drawing Creation

In this example, we focused on the VDC Detailer role and selected tasks related to modeling and shop drawing creation, including *1.1 Initial Preparation and Modeling, 1.2 Shop Drawing Submittal, 1.3 Model Update and Version Control and 1.4 Post-Construction Modeling*. Because of the variability in our dataset, applying stricter filters by trade or vertical market would result in a smaller number of available data points. So, for this demonstration purpose, we left the rest blank.

The right panel presents a boxplot of the filtered task percentage distributions. Each boxplot represents the spread of task time percentages across 89 project records (n=89), visualizing the central tendency and variation. The red square in each box denotes the mean value, while the black line represents the median. The scatter of individual data points helps identify outliers and assess the consistency of task allocations.

Statistical observations from Figure C-4 include:

- *1.1 Initial Preparation and Modeling* has a lower median time allocation of approximately 15–20%, with a wide interquartile range (IQR) and several outliers. This indicates a variability in how different teams approach initial modeling, likely influenced by differences in trade types or vertical market. Given this variability, it may be beneficial to further narrow down the dataset by filtering for specific trades or vertical markets to generate more comparable metrics.
- *1.2 Shop Drawing Submittal* has a median around 35% and shows a wide IQR. This suggests that it is both a time-intensive and highly variable task.
- *1.3 Model Update and Version Control* consistently receives the least time allocation, with both the median and mean below 10% and the narrowest IQR. This pattern indicates a relatively standardized task across projects.
- *1.4 Post-Construction Modeling* shows a high median time allocation (around 40%) with moderate variability. This reflects the labor-intensive nature of as-built model creation.

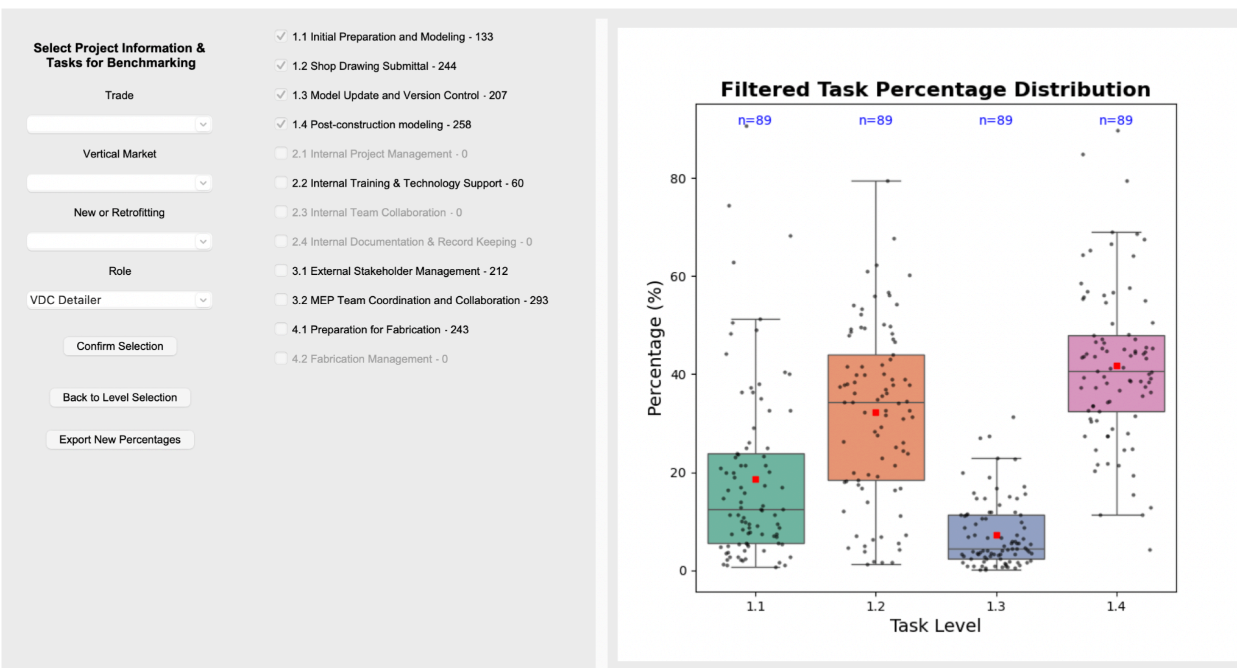


Figure C-4. Metrics for Modeling and Shop Drawing Creation

Now, users can apply this metric by benchmarking their ongoing projects using the same process described in Section C.2 to generate comparable results. For example, let's say a project reports time allocations of 18% for 1.1, 40% for 1.2 , 10% for 1.3, and 32% for 1.4.

When compared against Figure C-4., we can see that:

- 18% for 1.1 falls just below the mean, suggesting this project is fairly typical but slightly more efficient than average in the initial preparation phase.
- 40% for 1.2 sits near the upper quartile, indicating the project may be spending more time on shop drawing submittals than most other cases.
- 10% for 1.3 aligns with the upper end of the observed range, suggesting slightly above-average time spent on version control, which could be a signal of frequent design changes or coordination challenges.
- 32% for 1.4 falls slightly below the median for post-construction modeling, indicating efficient execution in this phase.

C.3.2 Benchmarking future project performance

In this example, we demonstrate how a project team can use the same dataset from Example B.3.1 to set performance improvement goals. This time, instead of focusing on detailed task-level data, we move to a higher activity level to gain a broader overview of how time is allocated.

Statistical observations from Figure C-5. include:

- *1 Modeling and Shop Drawing Creation* has a median around 30% with a wide spread.
- *2 Internal Management & Coordination* shows the lowest median (under 10%) and tight distribution.
- *3 External Management & Coordination* has a slightly higher median than Task 2 with moderate variability.
- *4 Fabrication Support* stands out with the highest median (~45%) and the widest range, indicating a time-intensive and variable task.

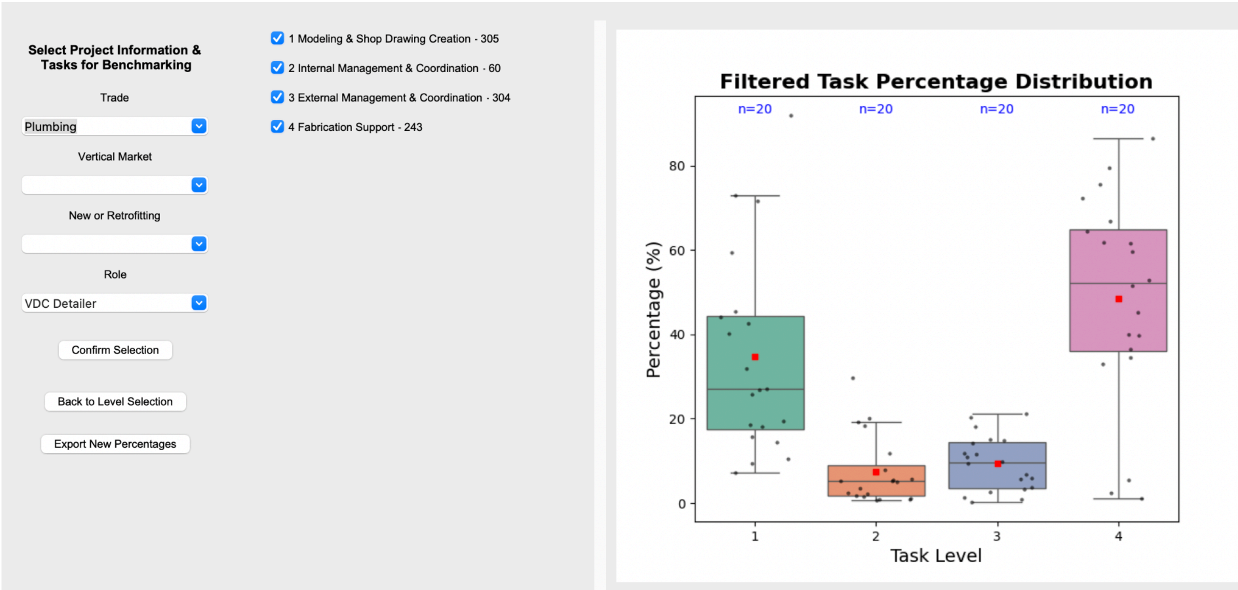


Figure C-5. Metric for All Level 1 Tasks

Goal for future projects

The existing project data shows a relatively high percentage of time spent on fabrication support, which may indicate a lower level of automation in this phase. Lower automation often leads to inefficiencies due to repetitive manual tasks and increased coordination needs. To improve the overall efficiency of the VDC work process, future projects should prioritize enhancing automation, such as automating shop drawing generation, and integrating model data with fabrication workflows. By streamlining these processes, teams can reduce time spent on manual work and focus more on value-added coordination and quality control. To learn more about automation in fabrication, refer to **Section 3: Assessment of the Levels of Automation in Fabrication Processes**, which provides useful insights into current practices and opportunities for improvement.