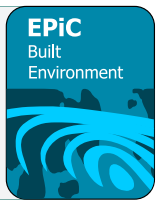
EPiC Series in Built Environment

Volume 4, 2023, Pages 20–27

Proceedings of 59th Annual Associated Schools of Construction International Conference




# HVAC Mechanical Contractors Framework for Effective Project Close-Out

**Jason D. Lucas, Ph.D., CGP; Dhaval Gajjar, Ph.D., FMP, SFP; Marchell B. Magxaka Ph.D. and Bishesh Bharadwaj**
Clemson University Clemson, SC

Project close-out activities and the transfer of information to the general contractor and owner are critical steps in meeting desired project outcomes and receiving timely final payments. This process, when not planned for, leads to delays and challenges that can harm a project's profitability and overall owner satisfaction. HVAC contractors are one of the major trades on construction job sites responsible for providing important facility operational information. If their close-out processes are not effective, they not only threaten their internal project success but can cause prolonged delays for other project stakeholders. This paper discusses a framework for project close-out for HVAC mechanical contractors. The research developed and analyzed fourteen (14) case studies documenting different companies' close-out processes. This allowed for identifying common challenges and existing workflows to determine how various companies addressed those challenges. The study resulted in a framework, represented as a process model workflow, to help HVAC mechanical contractors improve their internal close-out processes.

**Key Words:** Close-out, HVAC mechanical contractor

## Introduction

The Project Management Institute (PMI) (2008) formally defines "project closing" as the process of concluding all activities to formally complete the project, phase, or contractual obligations. Project close-out is typically the final stage of a subcontractor's project responsibilities. The project team demobilizes, documents are archived, punch list items are completed, and the project is handed over to the client. Project close-out in the construction industry has been challenging as the close-out process often lingers past project completion. According to Shay (2019), project stakeholders incur associated costs from this delay, such as construction loan interest, employee wages and benefits, insurance, and rental fees.

One of the critical scopes of work on any project is the mechanical systems. Over 12% of the overall project cost in the United States is attributable to mechanical systems (Ford, 2020). For more complex jobs, like healthcare facilities, laboratory buildings, and data centers, mechanical systems account for

significantly more of the overall project budget. In this respect, mechanical contractors play a significant role in the overall project success. Additionally, the mechanical systems are substantial to the function of the building by providing a healthy indoor environment (Simpeh et al., 2021). The efficiency of the mechanical system impacts overall energy consumption, which is influenced by faults in installation, system balancing, and ductwork leakage (Mirnaghi and Haghihat, 2020). Part of the close-out process is to verify the quality of these systems installed, document the efficiency of how these systems are running, and fine-tune the startup of the equipment (O'Connor and Mock, 2019). HVAC mechanical contractors have identified challenges to efficiently and effectively completing close-out tasks supporting the general contractor and owner's project needs (Magxaka et al., 2022).

This study aimed to identify a currently utilized process that can help HVAC mechanical contractors efficiently close out a project and successfully meet expected outcomes for the project. The research documented practices from various companies by developing case studies that were analyzed for challenges and practices utilized to overcome those challenges. The close-out processes used by these companies were documented as a workflow and analyzed for differences in how the companies addressed identified problems. From this comparison, a framework to support effective project close-out that addressed the identified challenges was proposed. That framework is discussed in detail in this paper.

## Literature Review

Closing out a project successfully goes beyond meeting budget and schedule constraints and relies heavily on meeting the owner's expectations of quality and service (Arantes and Ferreira, 2021). Since subcontractors are primarily responsible for performing 80-90% of the work, their performance heavily influences overall project success (Keshavarz-Ghorabaee et al., 2018). One way that many subcontractors meet project requirements is through project controls. These project controls often help gauge how a company utilizes its resources in generating successful project outcomes in closing out the project (Demirkesen & Ozorhon, 2017). Project controls go beyond budget and schedule tracking to reviewing quality periodically throughout the project. Common quality control activities utilized in construction for the close-out are the production of QA/QC reports and punch lists on behalf of the general contractor and/or owner (Vaughan et al., 2013). The timely receipt and completion of addressing issues on these reports and lists commonly result in project close-out delays (Tummalapudi et al., 2022).

Other factors that affect project close-out have been identified as coordination issues between trades, leading to design document flaws, slow change order approvals, and late payments (Gunduz & Elsherbeny, 2020). The handover of as-built construction documents and other building information to the owner is crucial to support the operations of the facility, however, it is often overlooked or poorly implemented (Zhu and Xu, 2021). Close-out requirements are often unclear with substandard contract clauses that do not effectively address the owner's desires or operational expectations for the roles and responsibilities of collecting the information. This leads to a lack of urgency from project participants to internally produce documents until requested closer to the end of the project, causing close-out delays (Arantes & Ferreira, 2021). Due to procedural issues, project close-out is not always successful (Hansen, 2021). Most project close-out challenges stem from human interactions and conflict among project stakeholders (O'Connor et al., 2019).

Current literature provides recommendations to mitigate project close-out challenges. Larsen et al. (2017) state that commissioning can reduce budget and time overruns by increasing early planning and organizational support, resulting in higher-quality technical systems and better end-user satisfaction.

Independent QA/QC professionals are recommended for effective commissioning, testing, and balancing (Mock & O'Connor, 2019). Johnson et al. (2017) suggest assessing techniques to improve final close-out documentation preparation, lowering the time designated for material checks, and establishing an internal task force to examine the organization's project close-out process. Other options include reducing paperwork using centralized and secure document management solutions, standardizing checklists (Johnson et al., 2017), and integrating a building operations expert at the design and construction stage to identify appropriate documentation needs (Elzarka, 2009).

However, the current literature does not provide any close-out processes that HVAC contractors in the construction industry are currently utilizing. This study fills an important gap in the literature by documenting such processes from various HVAC contractors.

## Methodology

The research aims to examine current workflows utilized by various HVAC mechanical sub-contractors to determine methods to address challenges during the project close-out processes. This was accomplished through a multiple case study analysis. The fourteen (14) case studies were developed utilizing semi-structured interviews. These interviews took place over Zoom, a web conferencing platform, and took between sixty (60) and ninety (90) minutes. The interviewees represented fourteen (14) different companies from across the United States, with one working internationally in Canada. The participants were in leadership positions (owner/president, vice-president, or senior project manager) within their respective companies. They knew the overall company policies and processes related to project close-out. To develop the case studies, the interviews were recorded and transcribed. The transcriptions were then coded through a constant comparison analysis allowing for iterative analysis of initial codes and secondary codes and eventually identifying overarching themes. QDA Miner Lite was used to support the coding analysis. The themes that emerged were either challenges, close-out strategies, or success measures. These thematic findings were previously published (Magxaka et al., 2022). As a follow-up to the initial part of the research, the study discussed in this paper reviewed the developed case studies and analyses of the individual workflows to propose a framework that HVAC mechanical subcontractors can use to improve their internal close-out processes. The case studies were reviewed to identify challenges faced by each company and then they were cross-analyzed with other case studies that did not report those same challenges. This multiple case-study analysis resulted in the proposed framework that is discussed below.

## Proposed Framework for Effective Project Close-out

Based on the case study analysis findings, activities that support project close-out were identified. These activities are based on processes identified throughout the case studies to support successful close-out. The workflow in the framework is organized based on the project lifecycle phase. The intended use of the framework is to allow companies to review their processes and evaluate where they might be able to improve. Common challenges that these strategic activities can help a company address include issues with communication, long (and delayed) punch-lists from other project stakeholders, unclear operational expectations in terms of document needs, schedule delays and conflicts resulting from change orders, document submittal delays, and challenges related to early demobilization. The activities incorporate strategies of identifying accountability, pre-planning, use of internal checklists, applications of lessons learned, and actively scheduling milestone meetings to help overcome the challenges. Figure 1 shows the proposed framework.

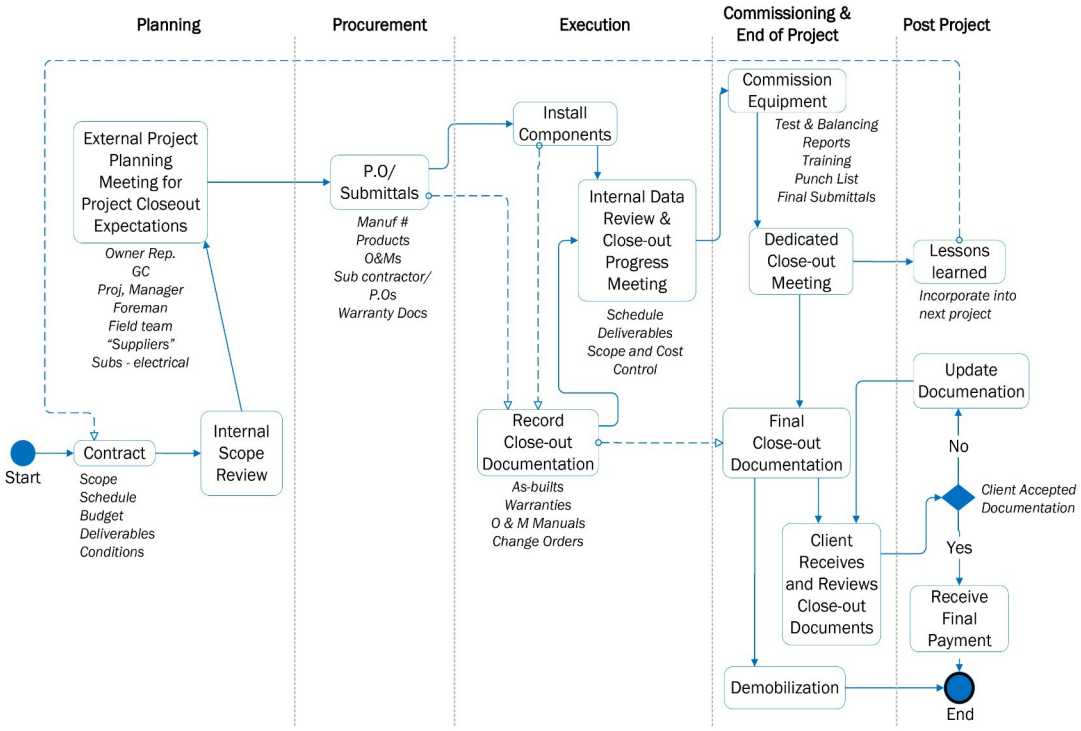



*Figure 1: Mechanical Contractor Close-out Process*

Not all companies in the case studies utilized all the activities, this workflow depicts a compilation of practices from a compiled review of industry practices. The incorporation of any of the included activities may be influenced by company size, the scope of the project, and the required project deliverables.

## *Planning Phase*

Successful project close-out greatly depends on the planning of the project as to how close-out activities are handled. The case studies revealed two processes that helped to set the project up for success. They both involve setting up appropriate operational expectations internally and externally with other project stakeholders. Those practices include the use of an internal scope review meeting and a project-planning meeting with external stakeholders.

1. *Contract/Internal Scope Review* – During the planning phase, the mechanical contractor's project team reviews the scope, schedule, budget, deliverables, and other contractual obligations related to project close-out. This meeting includes identifying internal checklists for QA/QC, setting milestones for supplying needed information, and determining project team responsibilities.
2. *External Project Planning Meeting* – This meeting is held with all the key stakeholders (internal and external) to understand the expectations and responsibilities related to project close-out documentation. Scope, schedule, budget, and deliverables are discussed and finalized with external partners. A key stakeholder, such as the owner rep and/or facility manager, that will be responsible for approving the project close-out package is identified. The owner's requirements and expectations regarding project close-out are identified, documented, and communicated proactively with the project team.

## *Procurement*

A lot of information about the equipment utilized in the building becomes available during the procurement phase of the project in the form of purchase orders and submittals. In many cases, owners require information about mechanical equipment to be documented in specific ways and provided at close-out. One method for promoting a more effective project close-out is to document this information when it becomes available. During the procurement phase, information related to the model numbers, material data samples, and O&M manuals can be proactively collected and organized in preparation for document close-out.

### *Execution*

Throughout the execution phase, information should be documented as it becomes available. This includes recording serial numbers and model numbers of equipment, changes to the drawings in producing as-built drawings, documenting approved change orders, maintaining an ongoing punch list of QA/QC activities and resolving them early, and compiling warranty information.

This information can then be reviewed during internal data review and close-out meetings. These meetings are where close-out documentation is checked throughout the execution phase by the management team and field team to discuss project status in terms of schedule, scope, cost control, and final deliverables.

### *Commissioning and End of Project*

During commissioning, the mechanical contractor facilitates the commissioning and startup of equipment, generating testing and balance reports, facilitating owners' training for successful equipment operation, resolving final punch list items, and compiling final submittals to turn over to the general contractor and owner. Once these are collected, a dedicated close-out meeting is conducted internally with the project team to discuss all aspects of the close-out documents and ensure they are complete and accurate before submitting them to the client. The finalized documents are then submitted for client review. Once this is completed, the team demobilizes and moves on to other projects.

## *Post Project*

After each project, it is important to identify lessons learned, document them, and incorporate them into future projects. Some information to consider during these lessons learned process include documentation requirements, the success of meeting those requirements, number and types of meetings and their effectiveness, nature of the type of owner and client relationships, payment time with contractor and vendors, approval time, internal team improvements, and overall close-out process improvements that can help on the next project. The lessons learned should be formally documented and shared with other project team leaders within the company.
Also, closely following the end of the project, the client should be provided a timeline to review the final close-out documents and request changes if necessary. These changes are easier to identify closer to the end of the project as possible, so information is not lost. The review of these documents often influences the final payment from the client as it may be withheld until any issues with the close-out documents are resolved.

## Discussion

For a company to take advantage of the findings of this research, it would need to review and benchmark its current processes and identify what challenges they need to address. To do this, key project team participants would need to be recognized that can review current documented close-out process protocols, if they exist. A benchmarking process to support this process includes the following steps:

1. Interview the key project team participants to identify different project close-out processes utilized by various team members within your company.
2. Compare the different close-out processes utilized from the interview and create a workflow of the typical close-out process used within the company. If a documented close-out process exists, check for compliance and effectiveness between the documented and implemented processes. Many companies identify having "understood" or formal processes but admit they are not followed.
3. Compare the findings from the internal company investigation and mapping to the proposed framework discussed earlier.
4. Identify activities from the proposed close-out process that may be appropriate for the company to implement based on the project scope, project size, and company size.
5. Update or create a documented close-out process for the company.
6. Disseminate, educate, and train on the process and then track effectiveness. It is important to revisit the process, ensure it is working as planned, and make appropriate adjustments.

## Conclusion

This paper discusses one phase of the research project that examined close-out practices utilized by HVAC mechanical subcontractors. As part of the research, case studies were developed documenting fourteen (14) companies' close-out processes. These cases were each documented in a workflow diagram and then cross-analyzed to identify how identified various companies were addressing common challenges. The identified processes were compiled into a proposed framework to help reduce the effect of challenges on closing out a project. This research addresses current challenges that mechanical contractors are experiencing in effectively and efficiently closing out projects.

The recommendations made from this study were specific to mechanical subcontractors. The general concept behind the framework is likely generalizable to other sectors of the industry, however, this would need to be reviewed in future research. It is reasonable to hypothesize that similar challenges in terms of timely and successful project close-out would be found in other industry sectors, however, some are specific to the mechanical contractors based on the types of equipment and work they are responsible for. Future studies will also include evaluating the proposed framework's effectiveness with companies implementing the findings.

## References

Arantes, A., & L.M.D. Ferreira. 2021. "A methodology for the development of delay mitigation measures in construction projects." *Production Planning & Control: The Management of Operations.* 32 (3), 228-241. https://doi.org/10.1080/09537287.2020.1725169

Demirkesen, S., & B. Ozorhon. 2017. "Measuring project management performance: Case of

construction industry." *Eng. Manage. J.*. 29 (4), 258-277. https://doi.org/10.1080/10429247.2017.1380579

Elzarka, H. M. 2009. "Best practices for procuring commissioning services." *J. Manage. Eng.* 25(3), 155-164. https://doi.org/10.1061/(ASCE)0742-597X(2009)25:3(155)

Ford, C. 2020. Cost of Constructing a Home. NAHB Economics and Housing Policy Group. https://www.nahb.org/-/media/8F04D7F6EAA34DBF8867D7C3385D2977.ashx

Gunduz, M., & H.A. Elsherbeny. 2021. "Critical Assessment of Contract Administration Using Multidimensional Fuzzy Logic Approach." *J. Constr. Eng. Manage.* 147(2), 04020162. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001975

Hansen, D. E. 2021. "Including Commissioning During Design Phase Benefits New Construction: a Qualitative Case Study." Doctoral dissertation, La Jolla, CA: Northcentral Univ.

Johnson, T. A., D.A. Michaels, R.E. Sturgill Jr. & T.R. Taylor. 2017. "Streamlined project close-out for construction at KYTC" (No. KTC-17-12/SPR13-460-1F). Kentucky Transportation Center, University of Kentucky, Lexington, KY. https://doi.org/10.13023/KTC.RR.2017.12

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2018). A dynamic fuzzy approach based on the EDAS method for multi-criteria subcontractor evaluation. *Information*, 9(3), 68. https://doi.org/10.3390/info9030068

Larsen, J. K., S.M. Lindhard, T.D. Brunoe, & K.N. Jensen. 2018. "The relation between pre-planning, commissioning and enhanced project performance." *Construction Economics and Building.* 18(2), 1-14. https://doi.org/10.5130/AJCEB.v18i2.5762

Magxaka, M, D. Gajjar, & J. Lucas. 2023. "Project Close-Out Process for HVAC Mechanical Contractors: Current Practices." *Journal of Construction Engineering and Management*. 149(2), https://ascelibrary.org/doi/abs/10.1061/JCEMD4.COENG-12394

Mirnaghi, M. S., & F. Haghighat. 2020. "Fault detection and diagnosis of large-scale HVAC systems in buildings using data-driven methods: A comprehensive review." *Energy Build. 229*, 110492. https://doi.org/10.1016/j.enbuild.2020.110492

Mock, B., & J.T. O'Connor. 2019. "High-value, low-effort industrial plant commissioning solution strategies." *Construction Innovation*. 19(4), 653-671. https://doi.org/10.1108/CI-09-2018-0072

O'Connor, J. T., & B.D. Mock. 2019. "Construction, commissioning, and startup execution: Problematic activities on capital projects." *J. Constr. Eng. Manage.* 145(4), 04019009. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001621

Project Management Institute, Inc. (PMI). 2008. *A Guide to the Project Management Body of Knowledge (PMBOK Guide), 4th ed*. (Newtown Square, PA: Project Management Institute, Inc., 2008), 11–16.

Simpeh, E. K., J.P.G. Pillay, R. Ndihokubwayo, & D.J. Nalumu. 2021. "Improving energy efficiency of HVAC systems in buildings: A review of best practices." *International Journal of Building Pathology and Adaptation*, *40*(2), 165–182. https://doi.org/10.1108/ijbpa-02-2021-0019

Shay, Z. B. 2019. "Factor that affect construction project close-out delay in 40/60 saving house project of Addis Ababa." Doctoral dissertation, Ethiopia: Addis Ababa Science and Technology Univ.

Tummalapudi, M., M. Harper, C., Taylor, T. R., Waddle, S., & Catchings, R. (2022). Causes, Implications, and Strategies for Project Closeout Delays in Highway Construction. *Transportation Research Record*, 03611981221087229. https://doi.org/10.1177/03611981221087229

Vaughan, J. L., Leming, M. L., Liu, M., & Jaselskis, E. (2013). Cost-benefit analysis of construction information management system implementation: Case study. *Journal of Construction Engineering and Management*, 139(4), 445-455. https://doi.org/10.1061/(ASCE)CO.1943-

7862.0000611

Zhu, L., M. Shan & Z. Xu. 2019. "Critical review of building handover-related research in construction and facility management journals." *Engineering, Construction and Architectural Management.* 28 (1), 154-173. https://doi.org/10.1108/ECAM-10-2018-0442