PennState College of Engineering | ARCHITECTURAL ENGINEERING

A Case Study in Lean Construction: Lighthouse Electric Company

By
Robert M. Leicht
John I. Messner
Elnaz Asadian

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The Pennsylvania State University
Architectural Engineering
University Park, PA 16802
USA

Summary

The continuous improvement approach at Lighthouse is centralized around a two-pronged strategy that focuses on their work packaging process and the supporting rapid deployment of technology. The well-defined process supported through standard operating procedures that are regularly referenced and updated offers a consistent and reliable procedure for complex electrical construction work.

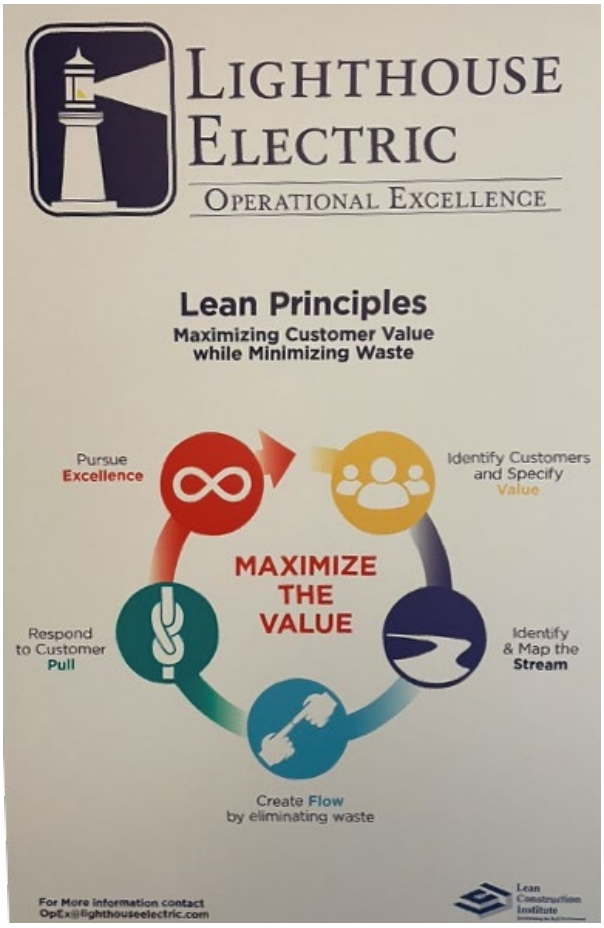
A strong focus on streamlining information and the use of thoughtfully applied digital tools underlay a strong technical approach. The balance of having core tools that are consistently used, coupled with the ability to rapidly create and test new digital processes, creates an agile basis for continuous improvement within their digital workflows. Linking these digital resources with their robust work packaging allows the team to develop the construction plan early in line with project needs. The use of a thoughtfully structured standard work breakdown structure that supports the prefabrication and work packaging allows consistency in how the planning and execution are developed and communicated to the field operations.

The strong emphasis on prefabrication in turn reduces the variability of production on projects. The extensive shop operations allow investment in new and emerging opportunities as Lighthouse continues to adopt creative solutions. Beyond managing simple in-house scopes, Lighthouse proactively engages with other trade partners to develop prefabricated work packages that reduce uncertainty and on-site congestion at intersecting scopes.

Leicht, R. M., Messner, J. I., and Asadian, E. (2022). A case study in lean construction: Lighthouse Electric. Case Study No. 04, Architectural Engineering, The Pennsylvania State University, Univ. Park, PA.

Company Overview

Lighthouse Electric was founded in the mid-1980s as a local Pittsburgh area, family-owned electrical contractor. In 2015, Lighthouse re-evaluated its business model and operations. With an emphasis on standardization, prefabrication, and continuous improvement they have been actively working to improve their delivery of value to their customers, as well as their internal (field) customers through their front-end planning processes and use of technology.



Delivery Methods

While Design-Bid-Build is a common delivery method used for pursuing and winning work, Lighthouse has increasingly been pursuing and winning projects that use integrated project delivery, as well as other forms that allow them to engage in the design processes of projects. They can bring their preconstruction knowledge, VDC processes, and approaches to prefabrication. While still limited opportunities to engage in design-assist roles, they are actively seeking opportunities.

Construction Scopes

Lighthouse focuses its work primarily in the commercial buildings sector, with an emphasis on technical buildings – such as airports, healthcare, and higher education. They have been expanding into the industrial and manufacturing sectors in recent years, as well as expanding their footprint into Virginia, West Virginia, as well as west Ohio.

Case Study Process

In late June 2022, the investigators of the Penn State Research Team conducted a site visit, performed interviews, and observed the operations at a construction project for Lighthouse Electric's headquarters, just south of Pittsburg, PA. The notes from the interviews and observations were reviewed to identify themes and the alignment of observed practices with principles of continuous improvement. Following the visit, the case study was documented and shared with personnel for validation. The case study document contains the description of how the behaviors and approaches to continuous improvement are implemented at Lighthouse to support their construction operations.

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Overview of Production Planning and Continuous Improvement at Lighthouse Electric Company

Lighthouse, in the initial stages of its transition toward more efficient operations, performed a large in-house process mapping activity to identify all the tasks and processes they perform across their projects. This process mapping activity helped to focus their efforts on those tasks they perform most commonly, and those that involve the most time and effort (labor hours) to perform. Building from the long list, they began prioritizing the processes, engaging their leadership from the relevant departments and operations, and defining their standard operating procedure (SOP) for performing each task. In addition to developing these SOPs to define the processes and details, they also developed a standard work breakdown structure (WBS) for their common construction tasks to apply across projects. The standard WBS creates a framework that allows consistency in the coding and tagging of information, specifically around labor and costs, to better enable both the language used across projects as well as the analytics to delve into their operations. This, in turn, refines their budgets to better fine-tune their estimates, labor planning, and ultimately work toward production improvements through work packaging and prefabrication. In particular, the process Lighthouse uses to take the design schematics and power plans, expands the information needed for the layout of conduit and circuiting that is critical in construction. The transition through the modeling process to enable work packages that consider racking, prefabrication, and kitting assemblies, plays a critical role at the hub of their processes.

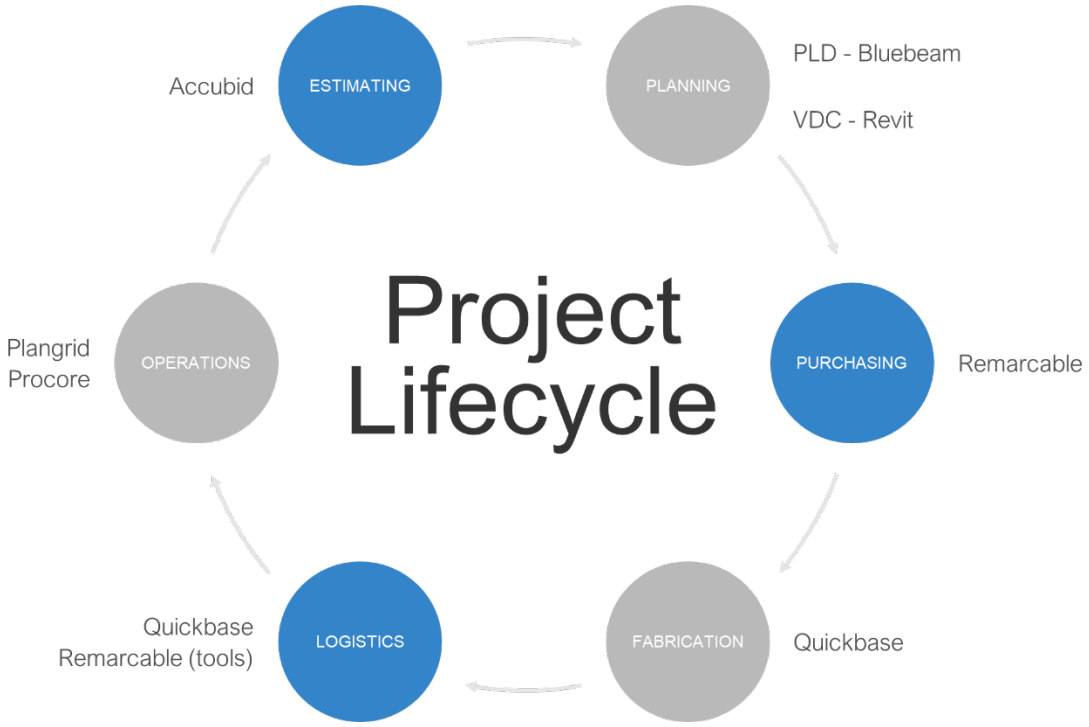

Figure 1: Project Lifecycle with supporting software tools.

Some of the elements that serve as key methods and procedural contributors to that strategy are the standardized work efforts, both in defining the process and procedures, as well as standardizing components and assemblies that allow automation in the VDC process. Kitting of parts plays a critical role

in the secondary logistics on the job site to help move materials to the rooms or locations where the work takes place. Prefabrication allows the kitting to expand into larger assemblies that can be placed using duct lifts or lulls. In addition, Lighthouse actively seeks opportunities on projects with related scopes, such as mechanical, where the intersection of trade work can lead to uncertainty, confusion, and conflict. To address this, they try to collaborate and engage in prefabrication that allows them to perform the electrical scope offsite.

Work Packaging using models

The Planning, Layout, and Design (PLD) process takes the schematic design from the electrical engineer of record and the power plans, reviews the full array of drawings to develop the conduit routing, and identifies nodes for circuiting. In the process, the circuiting, wiring sizing, and parallel design information (e.g. panel circuit references) are incorporated into a Bluebeam document in which the conduit layouts are overlaid onto the construction documents. The electrical system and circuit information is extracted, with the feeders labeled, and imported into Revit as the 3D geometry for the feeder to be modeled. The feeder label serves as an ID for importing the design and bill of material data that would otherwise be manually added to the model.

Figure 3: Dan Radocay explaining the process of breaking down a floor p

As the feeder models are developed from the Bluebeam 2D layout into a 3D model in Revit, automated processes in Dynamo are used, post-coordination, to incorporate fabrication information into the geometry. For example, drawing the couplings on the conduit can be done in one location and duplicated at set spacing, 10’ or 20’, for an entire run. Similarly, the Dynamo codes can duplicate parallel feeder runs or duplicate trapeze or other supports. Some manual adjustments may be needed to

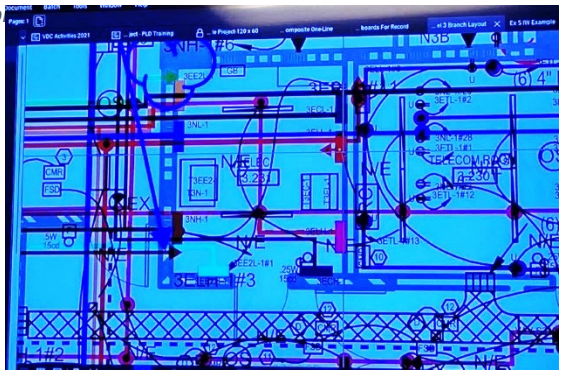

Figure 2: Conduit layout over power plan in Bluebeam.

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avoid clashes, but the automation drastically reduces the otherwise manual process of detailing the conduit for future racking and fabrication.

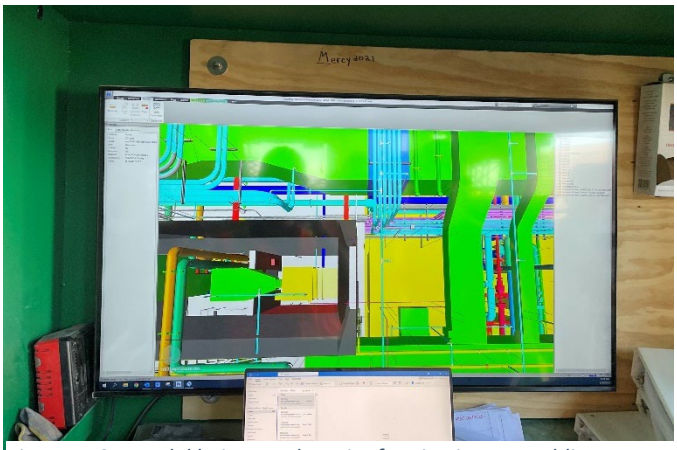


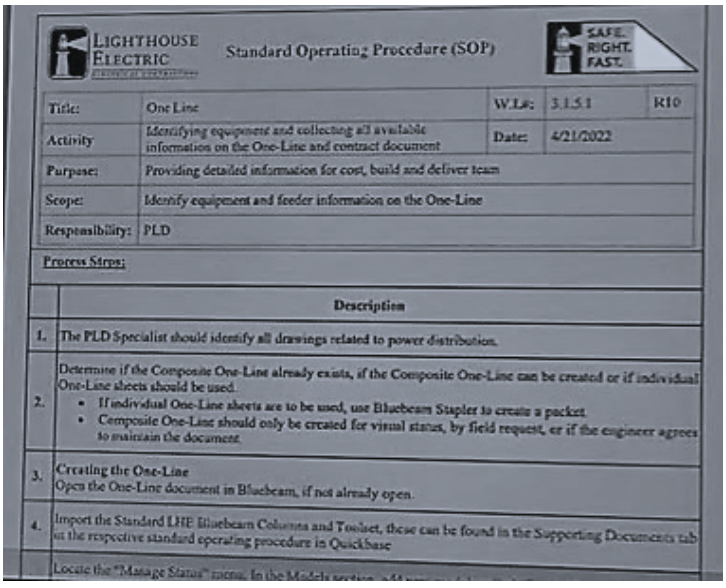
Figure 4: 3D model being used on site for viewing assemblies.

The racks and related assemblies are incorporated into spool drawing sheets, again using automation to streamline the population of the drawings. Some manual detailing is needed to complete the spool sheets that are fed to the fabrication shop. Each sheet is coded with a QR code both to the SOP for that assembly, as well as a link to the 3D model geometry to help clarify any questions that may arise in fabrication.

Standardized Work

The effort to create SOPs for core tasks has led to the creation of approximately 60 SOPs, with the modeling and prefabrication processes leading in terms of areas for creating and updating. The process is expanding across departments, with recent progress in preconstruction and discussion of working on field operations in the near future. In addition to creating the SOPs to define how the process should work, the SOPS further serve as training resources when personnel is onboarded into the company as well as move between roles. They provide detailed information about what drawings or views are needed for a given task, what other information should be sought (e.g., RFIs or submitted documents), and provide checklists or other simple instructions to allow self-checking. The SOPs are hosted online, allowing QR codes for each to be easily embedded into relevant documentation, for example, the QR code for the rack fabrication SOP is a standard element in the template spool drawing for each rack sheet that is created.

The company has further tried to enhance the engagement with the SOPs by distributing responsibility for each, and the knowledge of its implementation, across personnel. This creates shared ownership, as well as translating the otherwise passive documents into a live knowledge network within the company. Thus, rather than serving as 'just another document' the network of company expertise is defined. When a question about how to perform a process or a potential improvement arises, it leads to engagement with the person that is responsible, leading to increased interconnectivity of people that are the leading internal experts.



LIGHTHOUSE ELECTRIC — Standard Operating Procedure (SOP) — SAFE. RIGHT. FAST.

Title:	One Line	W.I.#:	3.1.5.1	R10
Activity	Identifying equipment and collecting all available information on the One-Line and contract document	Date:	4/21/2022	
Purpose:	Providing detailed information for cost, build and deliver team			
Scope:	Identify equipment and feeder information on the One-Line			
Responsibility:	PLD			

Process Steps:

	Description
1.	The PLD Specialist should identify all drawings related to power distribution.
2.	Determine if the Composite One-Line already exists, if the Composite One-Line can be created or if individual One-Line sheets should be used. • If individual One-Line sheets are to be used, use Bluebeam Stapler to create a packet. • Composite One-Line should only be created for visual status, by field request, or if the engineer agrees to maintain the document.
3.	Creating the One-Line Open the One-Line document in Bluebeam, if not already open.
4.	Import the Standard LHE Bluebeam Columns and Toolset, these can be found in the Supporting Documents tab in the respective standard operating procedure in Quickbase
	Locate the "Manage Status" menu. In the Models section, [illegible]

Figure 5: Snapshot of an example Standard Operation Procedure.

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Work Breakdown Structure

While Work Breakdown Structure (WBS) is considered a common term in construction in some regards, they are often highly varied in their structure and implementation between firms and projects. A thoughtful WBS serves to organize the facility design under construction based on the tasks undertaken to construct the components, systems, and ultimately the entire facility. By standardizing the WBS for Lighthouse's common systems and tasks, as shown in Figure 6, they can standardize the naming, structuring of estimates and schedules, and the resulting production plans. This creates a common language and source of information when reviewing past projects, assessing the success of new approaches, such as prefabrication, and allows a greater level of detail in the analysis. Coupled with their use of Quickbase to rapidly assign the work packages and scopes for the project to the corresponding scopes, the structure provides a clear and consistent framework for organizing work around production. The ability to drill into the data, such as determining time spent modeling racks, fabricating them, and installing them, in turn, leads to a clearer understanding of the sources of variation across projects. It serves to quickly provide the estimated labor to project managers and field leaders to understand how the Preconstruction team planned the project.

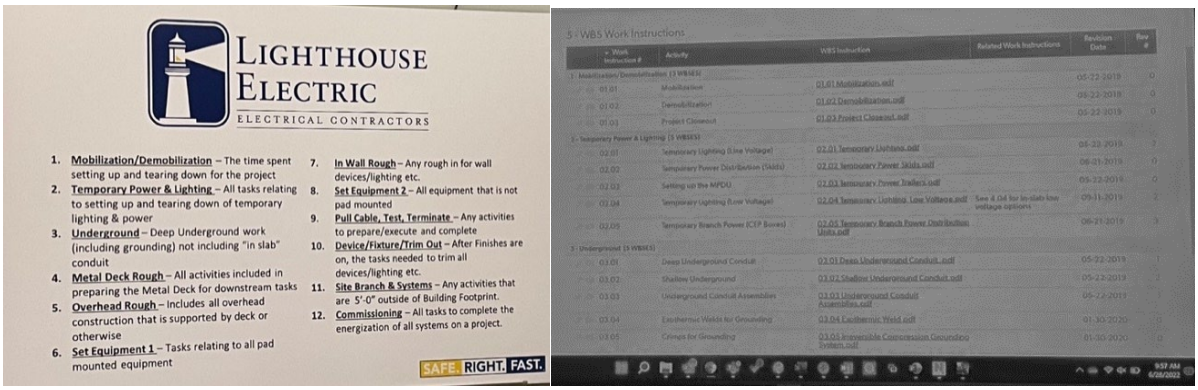

Figure 6: Standard WBS convention (left) and example project activities (right)

Visual Management

The use of color coding for common system notation in the Bluebeam and model files offers a visual management strategy for everyone to be able to quickly identify or differentiate among the systems. The further use of QR codes on drawings allows quick access to and references for the spool sheets as rich visuals. The field teams employed magnetic labels of field crews that included pictures to allow a quick recognition of personnel and a simple system of turning them upside-down if that worker was off.

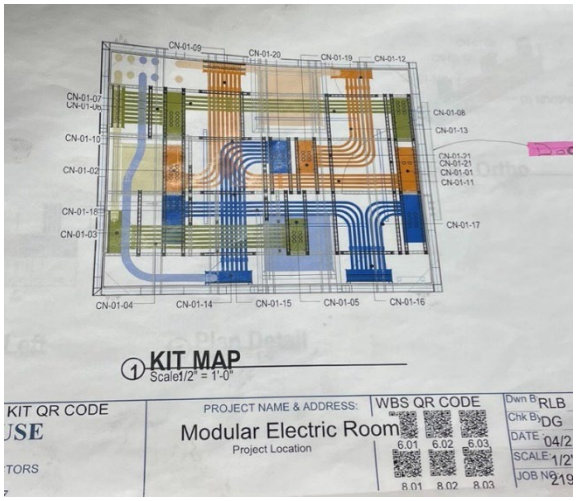

Figure 7: Visual kit mapping of electrical scope.

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Work packages for Prefabrication and Kitting

Referred to as 'Kits' – the prefabrication process is initiated by breaking down the project into work areas, based upon the overall project schedule, that corresponds to electrical work packages. The work packages drive the organization of the prefabricated racks, the labeling of kits by area and then the room, as well as allowing easy naming to match with the project naming and scheduling convention. Racks are shipped to the site on pallets. The kits, usually stored in blue totes as shown in Figure 8, for in-wall fit rough-in are organized by room. Carts for moving the totes were customized to allow easy stacking and strapping that supports both shipping to the site and movement within the facility under construction, reducing the waste often associated with moving materials. The spool drawings provide a key, or 'kit map,' as shown in Figure 7, to show where each of the prefabricated scopes will be installed. Each tote contains a drawing for that individual room to quickly convey where the outlet box or other device should be installed.

Figure 8: Kitting (left) and prefabricated racks (right) ready for shipping and installation.

Collocation

For new projects and intense reconstruction efforts, Lighthouse encourages collocation of personnel, to the extent possible. Learning from the cross-functional teams they have engaged with in IPD projects, they try to engage with their trader partners and GCs when they are involved in preconstruction efforts. When there are limitations, as seen recently with Covid-19 concerns, they have set up in-house collocation between their PLD and modeling processes to allow easy sharing and discussion, as shown in Figure 9, with the use of Microsoft Teams to expand the collaboration virtually to other trades, the GC, and designers.

Figure 9: Internal collocation for a project in Lighthouse's office.

Central information management for purchasing *(https://www.remarcable.com/)*

Lighthouse was an early beta-tester for software that is now widely available to electrical contractors, titled Remarcable. Remarcable serves as both an online store to quickly find and price common items, receive quotes, and purchase materials. In addition, to serve the challenges of construction site logistics, the app is structured to allow project teams to quickly access the material they have purchased but is being held in vendor warehouses. They can request quantities be shipped to the site as needed, reducing on-site congestion. The purchasing process also allows for vendors to flag off-the-shelf items, so field teams can recognize readily available vs longer lead time materials or supplies. The application similarly allows for the 'requesting' of in-house equipment and tools from the Lighthouse shop, with easy tracking and accountability for their return. The centralization of the information allows for purchasing to be able to extract and trend material purchases and use patterns to support forecasting and estimating efforts on current and future projects.

Collaborative Prefabrication

Lighthouse tries, when allowed by the delivery method and relationship with other trade partners on a project, to pursue prefabrication that reduces the uncertainty in their on-site production work. As highlighted in Figure 10, on a recent hospital project they coordinated for the mechanical contractor to deliver the variable-frequency drives (VFDs) for the project to Lighthouse's shop. Lighthouse fabricated a rack to mount the VFDs and was able to include their electrical panel and wiring of the VFDs offsite. When working on site, they simply need to mount the rack and make the connections to panel, and then quickly handing off the scope to the mechanical trade for their connections to the associated mechanical equipment.

Figure 10: Prefabricated rack of VFDs (left) in the shop and (right) installed at sight

Concluding Thoughts

Throughout the visit it was clear that Lighthouse has a strong combination of production planning with their adoption of technology that allows them to be at the leading edge for modeling and prefabrication. The movement toward work packaging allows their in-office planning to be able to support the processes and work breakdown that best enables the on-site operations.

Practices that support lean

- Consistency of Work Breakdown Structure and work packaging process to support planning and prefabrication opportunities.
- Strong focus on defining standards and procedures. While not complete, there was an ongoing effort to expand the SOPs across the company.
- Shared ownership – the structure of subject matter experts for each SOP to allow everyone to have some ownership, but also define the 'people' that hold the knowledge, with the SOP as a resource for information
- Constant effort to improve – PLD and VDC had ~ 60 SOPs, and for example SOP that was discussed, it was on version 25.

Common challenges and barriers

- Strong success with overhead, limited success with in-wall efforts to date due to lack of modeling and layout of in-wall circuit runs
- Slower buy-in from field personnel – While there was growing use and support of kits and racks, there was still limited adoption of field-oriented planning that stemmed from the adoption of lean practices.

Other Observations

Analytics and Data Science

The internal efforts to rapidly adopt and prototype software tools were one of the differentiators of Lighthouse's processes. While the tools and the agility with which Lighthouse develops and deploys them are impressive, it appears that an investment in data science and analytical approaches to extracting and leveraging the extensive data and information resources could give Lighthouse a significant advantage. Organizing and centralizing the data from past projects could pose rich insights into trends or patterns that are not apparent to the human eye, they would provide a rich set of metrics for monitoring and forecasting resource or personnel needs, and the ability to dive into unusual circumstances more deeply.

Weekly Work Planning

The use of field-led weekly work planning, including using daily huddles and visual management techniques of the building floorplan could offer significant value in the creation of crew routines. The engagement of field operations in daily huddles to discuss recently completed work, train workers in the planning of current and upcoming work, and leveraging the knowledge of operations on the ground to identify upcoming constraints or needs to funnel to project leadership had ample opportunity for improvement. The further ability to leverage pull planning systems and visual management to streamline

these efforts would greatly extend the value of the adopted methods beyond the current success in the prefabrication shop.

Opportunity for standard tracking/reporting of key production numbers across projects
While the standardization of WBS and accounting was widely used, the use of this system to create quick dashboards and visuals for tracking and communicating this during on-site construction would be an invaluable next step. The information is well structured in the preconstruction, modeling, and fabrication processes, and taking the next step to create a simple dashboard or charting of those same elements regarding on-site installation would provide easy to assess progress or constraints, as well as moving toward standardization of project tracking and communication. This would allow personnel moving between projects to quickly get attuned to a new project, recognize the status, and understand how they can engage and support the project. The coding would not need to track every WBS and accounting element, but key performance indicators or budget items from the WBS could be used as common indicators.

Acknowledgments

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