Using Project Production Methodology to Compare Onsite Prefabrication Steel Erection to Traditional Stick-Built

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Project production management provides continuity, predictability, and optimization of a process in comparison to the traditional approach of project management. Prefabrication is an example of project production management in which there is continuity of the product, reduced variability, and where the assembly process can be altered for best results. This paper will examine the benefits of project production management and compare two methods of steel erection in which one method performs an onsite prefabrication process while the other method employs the traditional stick-built process. The two methods will be modeled by a tool that replicates a repetitive process similar to a production system through the use of symbols. This tool also enables data like the duration of tasks, the required demand of the system or assembly, the amount of inventory available to be inputted, and can also calculate the capacity utilization of machinery or crews working. The two different methods will be analyzed through the scope of project production management using a tool called a Process Mapper. The resulting conclusion will be that the onsite prefabrication method will be shown to better utilize labor resources and be a safer approach in comparison to the traditional method.

Key Words: Project Production Management, Prefabrication, Steel Erection, Optimization, Capacity Utilization

Introduction

Traditionally project management is used for the execution of construction projects. Project management is the process in which administrative techniques are implemented to meet project requirements and goals. Project management is constrained by scope, budget, and schedule. The limitations of project management are the inability to control project predictability, continuity, and optimization. Project production management improves the delivery of the traditional project management process by incorporating operations science. Operations science focuses on demand, production, and variability to better enhance an operation process. The fusion of operation sciences
and project management creates project production control which organizes and controls production work. This results in the optimization of the construction process by examining the project as a production system that can be easily evaluated and adjusted for best results. Project production management is constrained by product design, process design, capacity, inventory, and variability. The five constraints, also called the Five Levers of Optimization, controls scope, budget, and schedule but also enable more control of the project by providing continuity of the production system, predictability of the system, and accessibility to altering and optimizing production processes. (Project Production Institute 2022)

**Visualization of the Assembly Process**

Project Production Institute (PPI) is a consortium of industry scholars and professionals who employ project production management to best improve project outcomes. PPI utilizes project production management not just for construction projects, but for any process that can be represented as an assembly system. PPI developed a tool called the Process Mapper which models production processes and systems through symbols. “The Process Mapper enables this by providing a simple and clear language for defining the activities, queues and resources required within a production process” (Project Production Institute 2022). The Process Mapper uses symbols like a cylinder, rectangle, and triangle to be symbolic of material stocks, queues, and operation activities as illustrated in Figure 1.

![Figure 1. Example of the Process Mapper](image)

Additionally, the Process Mapper is able to detect areas of bottlenecks, the overall capacity of equipment, and the utilization of equipment. A construction project is commonly analyzed and orchestrated by schedules and critical paths. “Traditional scheduling methods such as critical path method (CPM), program evaluation and review technique, or precedence diagram, are valuable tools supporting management in the construction industry but are unsuitable for planning repetitive construction projects” (Tomczak & Jaśkowski 2020). Construction projects can be analyzed as an assembled system devised of many assembly processes, especially repetitive projects. A major application of project production management in construction today is in prefabrication. Prefabrication is the process of assembling material in a controlled environment. Supervising the assembly limits variability, ensures predictability and continuity of the material and assembly, and allows for alterations of the processes to optimize the assembly.

**Onsite Prefabrication**

Building Zone Industries (BZI) is a steel erection company specializing in the creation of big box stores, warehouses and distribution facilities, and other steel specialties. BZI, in partnership with Innovatech, created a panelization table system that creates a panelized system on the ground and can be lifted into place as shown in Figure 2. Common stick-builts install the joists followed by metal decking sheets one after another at elevated heights. The innovation of the panelizing system enables a portion of the steel system to be prefabricated on the ground and to be lifted into place. The
prefabrication process reduces the amount of time workers are at elevated heights. “Roof fatalities accounted for one-third of fatal falls in construction in 1992–2009. A disproportionately high percentage (67%) of deaths from roof falls occurred in small construction establishments (1–10 employees). Roofers, ironworkers, workers employed with roofing contractors, or working at residential construction sites, had a higher risk of roof fatalities” (Dong 2013 17). Camille Haight the director of public relations at BZI stated, “We only need to have two guys on the roof at a time to place the panels, which means fewer employees working from dangerous heights… It’s about risk management. Less exposure equals an exponentially safer work place” (Gregg 2017 3). The panelized system produces a safer environment for its workers. In addition to providing a safer alternative to traditional stick-built steel buildings, the prefabrication process provides continuity of the panelized system and reduces the variability of the erection process because of the controlled repetition of the process.

Figure 2. Innovatech Panelization Equipment

Source: Building Zone Industries

Objective

The prefabricated panelized system provides increased safety due to the reduced time workers are at elevated heights. The goal of this research is to use the Process Mapper to identify other benefits of the onsite prefabrication process. Utilizing the Process Mapper, researchers are able to analyze the capacity utilization of the crews using the prefabrication assembly process in comparison to crews using the traditional stick-built method. Capacity utilization is the maximum average rate at which products can flow through a process during a measured duration in which the equipment does not become idle.

Methodology

First, a standardized commercial warehouse was modeled in Revit, a building information software, so that both types of construction could be applied to the same building. The modeled warehouse was two stories and 224,000 square feet. The building was composed of 140 bays. Each bay was devised of four columns, fours beams, six joists, and thirty-two metal decking sheets as illustrated in Figure 3.
The Revit modeled commercial warehouse and the demand remained constant between both methods of steel erection.

Figure 3. Revit Model of the Standardized Commercial Warehouse

Next, an interview was conducted with the regional manager of operations of the west coast for BZI. The responses of the interview are as follows:

- The standard bay size that BZI builds is 55’ x 66’.
- The duration of a 224,000 square feet warehouse with 140 bays would be ten days, including set-up and detailing, to erect.
- The amount of square feet BZI completes on average per day is 35,000 square feet.
- The average number of panelized systems built per day is 40 to 45.
- The panelizing table can create a panelized system in ten minutes.
- The duration of the transportation of the panelized system from the panelizing table to the incomplete bay is three and a half minutes to seven minutes.

Figure 4. A Revit Model of a Panelized System Consisting of Joists and Metal Decking in an Exploded View

The onsite prefabrication process used by BZI was modeled using the Process Mapper. The panelized system operation is the placement of joists on the panelizing table system followed by the attachment of the metal decking sheets to the joists as depicted in Figure 4. The process models the erection of the columns and beams for the bays. Concurrently, the fabrication of the panelized
system is modeled. The panelized system is transported and is installed into the incomplete bay. Once all the bays have the panelized systems installed, the bays are then complete. The process continues until all the bays in the structure are complete. The information given from the interview was then input into the Process Mapper to be analyzed. Figure 5 shows the process from the interview that was built into the Process Mapper.

![Figure 5](image)

**Figure 5. The Modeled Onsite Prefabrication Process**  
(See Appendix A for the larger-scale modeled process)

The traditional method of constructing a warehouse was also modeled using the Process Mapper, as shown in Figure 6. Similar to the other method, the erection of the columns and beams were modeled. However, the joist transportation and installation were not concurrent with the beam and column erection and were modeled to follow after the incomplete bay erection. After the joists had been placed, the metal decking sheets transportation and installation were modeled. This detail had to be added because the metal decking sheets installation and transportation were not concurrent with the incomplete bay erection and joist installation.

![Figure 6](image)

**Figure 6. The Modeled Traditional Stick-Built Process**  
(See Appendix B for the larger-scale modeled process)

The information used from the interview with BZI was also used in the traditional method modeled process, as shown in Figure 6. The duration for column and beam erection, transportation of that material, and the erection of the additional bays remained constant between both models. However, the time to install the joists and metal decking was increased by 30% due to the longer durations that crews are exposed to elevated heights.
Results

The Process Mapper enabled the two types of steel construction, the onsite prefabrication and traditional methods, to be quantitatively comparable. The Process Mapper also allows the different processes to be analyzed through a project production management scope. The tool allowed for control of the levers of process design, capacity, inventory, and variability. The control of these levers implements the creation and modification of a more optimized design of an assembly process. The onsite prefabricated process used by BZI demonstrates reduced capacity utilization in the areas of transportation, joist installation, and complete bay erection. The reduced capacity utilization means that the crews are being utilized less to meet the demand of production. If the capacity utilization becomes too high or exceeds one hundred percent, then additional crews may be needed to achieve the desired demand. The process centers that remained the same between the two methods were incomplete and complete bay erection crews. The onsite prefabrication method required a crew to place the joists and metal decking sheets upon the panelization table system and a crew to transport the panelized system to the incomplete bay shown in Figure 7. The traditional stick-built method required a crew to transport the joists and metal decking sheets to the incomplete bay and have crews place the joists followed by the metal decking shown in Figure 8. The traditional stick-built method required additional crews, like in the complete bay erection process center, in order to produce similar results as the onsite prefabrication method. The results of the comparison of the traditional method to the onsite prefabrication method demonstrated that the demand is less strenuous on the crews of the onsite prefabrication method.

![Graphed Capacity Utilization](See Appendix C for the larger-scale capacity utilization graph)
Conclusions and Future Research

Project production management provides better control of predictability, continuity, and optimization of a project in comparison to project management. Evaluating a construction project through project production methodology enables the project to be analyzed as processes and operations rather than critical paths and schedules. It is common to be taught to evaluate construction projects from a project management standpoint, especially how to schedule and create critical paths. Evaluating the construction of the commercial warehouse from a project production management standpoint was difficult. Transitioning the analysis from schedules to operations was a learning curve. However, the Process Mapper aided in the understanding of project production management. Having the ability to analyze construction projects through another perspective besides project management will better suit the construction industry, especially prefabrication and repetitive projects. Steel erection, in the case of a commercial warehouse, was evaluated as a repetitive project. Control of the product design, process design, capacity, inventory, and variability ensured optimization of the project. The onsite prefabrication method of steel erection is an example of project production management. The onsite prefabrication method was shown to be more optimized in comparison to its counterpart, the traditional stick-built method. Utilizing project production methodology can help construct projects more efficiently. The Process Mapper tool helps evaluate projects as assemblies and operations. Additionally, the Process Mapper can help optimize assemblies and operations by analyzing the utilization of resources.

Future Research

Future research could be a time-motion study in which the durations of tasks are measured in person and on actual projects. The time-motion study could involve multiple steel erection companies rather than just one. A comparison of two different steel companies each using a different method of steel erection may display which method is optimized in real-time. However, constraints and constants would have to be set to ensure the methods are evaluated equally without bias. Another possibility of
future research could be a cost analysis of the two methods of steel erection could be performed. The Process Mapper has the capability to analyze cash flows of processes and operations. The cash flow analysis of the Process Mapper includes costs like the price of inventory and labor wages. Interviews and research of steel erection companies of the cost to perform different methods of steel erection could be input into the Process Mapper. A cost analysis may be appealing to steel erection companies to see if the optimization of the project is profitable.

Citations


The Modeled Onsite Prefabrication Process

For more information, please contact Project Production Institute to view full model.
Appendix B

The Modeled Traditional Stick-Built Process
(Process has been rotated to be readable on the page)
For more information, please contact Project Production Institute to view full model.
The Graphed Capacity Utilization of the Onsite Prefabrication Method Process Centers (Graph has been rotated to be readable on the page) For more information, please contact Project Production Institute to view full model.
The Graphed Capacity Utilization of the Traditional Stick-Build Method Process Centers
(Graph has been rotated to be readable on the page)

For more information, please contact Project Production Institute to view full model.