

INCLUSION OF LEAN CONSTRUCTION IN CONSTRUCTION EDUCATION

Wilfred H. Roudebush¹

ABSTRACT

Construction industry firms are becoming aware of the benefits of lean construction and are interested in its implementation. There exists a need for education and training of individuals in the implementation of lean construction fundamentals. Institutions offering traditional construction education should consider inclusion of state-of-the-art lean construction fundamentals into their academic curriculum.

This paper will present an example of a lean construction laboratory project conducted in the CONS 235 Introduction to Construction course of the Construction Management program at Bowling Green State University in Bowling Green, Ohio. Because of the introductory nature of the course, a limited number of fundamental theories of lean construction were covered. The laboratory project sessions served as a place to teach these fundamental theories. This paper documents the outcomes of application of a limited number of lean construction fundamentals and is not presented as a formal research project. A challenge for construction education is to incorporate lean manufacturing fundamentals in a construction education environment. Construction industry firms will benefit from the inclusion of lean construction in construction, construction technology, and construction management education.

KEY WORDS

Lean construction, Lean construction fundamentals, construction education

INTRODUCTION

The knowledge of lean construction fundamentals to eliminate various types of waste has been established for some time. Excellent sources of information on the various types of waste are (George 2003), (Womack and Jones 2003), and (Liker 2004). Inclusion of lean construction fundamentals in construction education is at an early stage. Lean construction is a paradigm shift from traditional construction. Most construction and construction management firms still focus on traditional construction processes and techniques. Many of these firms are aware of the existence of lean construction but are sceptical about incorporating it on their construction projects.

A role of construction education is to research, develop, and apply new construction paradigms, such as lean construction, through the education of construction, construction technology, and construction management students in construction education curriculums. Many of these students are aware of the existence of lean construction, but do not know the fundamentals of lean construction. They are interested in learning and applying these fundamentals.

The purpose of this paper is to present a hands-on lean construction laboratory project conducted in the sophomore CONS 235 Introduction to Construction course of the

¹ Associate Professor, Registered Architect, Construction Management and Technology Program, College of Technology, 264 Technology Building, Bowling Green State University, Bowling Green, Ohio 43403, Phone (419) 372-8275, FAX (419) 372-6066, wroudeb@bgsu.edu

Construction Management program at Bowling Green State University in Bowling Green, Ohio. Because of the introductory nature of the course, a limited number of fundamental theories of lean construction were covered. The project consisted of the construction of four sidewall panels for two Habitat for Humanity sheds. Field assembly of the sheds was not included as part of the course. Fabrication of the wall panels was divided into four construction laboratory sessions where lean construction fundamentals were introduced and applied. The laboratory project sessions served as a place to teach these fundamental theories. The four laboratory sessions were patterned after a Lean 101 training seminar conducted by the Edison Centre in Toledo, Ohio, that the CONS 235 instructor attended.

METHODOLOGY

Fabrication of the four 8'-0" high x 10'-0" long sidewall panels was used to teach lean construction fundamentals. A detailed fabrication drawing of the wall panels was provided to students for construction of the wall panels. This drawing included: top and bottom plates, stud locations and spacing, and overall panel dimensions. The fabrication was divided into four separate class sessions conducted over a two week period. Each laboratory session was two hours. Approximately 20 students (Construction Management, Architecture, and Interior Design) participated in each of the four laboratory sessions of the CONS 235 Introduction to Construction course. Laboratory descriptions and results follow.

LABORATORY SESSION ONE (WEEK 1)

Lean Construction was introduced as a paradigm shift from traditional construction. Lean construction fundamentals were not presented during the lecture portion of laboratory session one. Students were told fundamentals of lean construction would be introduced during laboratory sessions two, three, and four.

Before going to the laboratory area to construct the first wall panel, a detailed sketch was made on the whiteboard and the four laboratory sessions were briefly described. The description of laboratory session one purposefully did not include any details on wall panel construction techniques. Students were to develop and apply these during construction of the first wall panel.

- One 8'-0" high x 10'-0" long sidewall panel was constructed.
- Traditional construction techniques were utilized. No lean construction fundamentals were taught to the students prior to fabrication and assembly of the first wall panel.
- Students were provided a detailed fabrication drawing, lumber for the top plate, bottom plate and studs, nails, tools, safety glasses, and access to a radial arm saw. A student with power equipment experience was designated to use the radial arm saw.
- The laboratory instructor provided no guidance during the construction process. Students made all construction decisions. A stopwatch was used to time the duration to fabricate and assemble the first wall panel.

RESULTS OF LABORATORY SESSION ONE

After constructing the first wall panel, the class met in the lecture area to discuss what took place. Student moral appeared to be low because of the chaotic construction environment that took place. The instructor queried students on improvements they would recommend implementing during laboratory session two. The main recommendation was better use of students (labour) during the construction process.

- Total time to fabricate and assemble the first wall panel was 26 minutes.
- Various types of waste were observed during laboratory session one that include: replacement of broken or improperly installed wall components (correction of mistakes/defects), many students standing around with nothing to do (waiting and human intellect), much movement of students fabricating and assembling the wall panels (motion), and excessive movement of wall components (transportation).

LABORATORY SESSION TWO (WEEK 1)

- Prior to construction of the second wall panel, students met with the instructor in the lecture area to discuss wastes observed by the students. Students provided input on how to improve the wall panel construction process. The instructor taught a few specific lean construction fundamentals prior to fabrication and assembly of the second wall panel.
- One 8'-0" high x 10'-0" long sidewall panel was constructed.
- The following lean construction fundamentals were taught to the students prior to wall panel fabrication and assembly: types of waste to eliminate (waiting, correction of mistakes/defects, motion, and human intellect) as described by (George 2003), (Womack and Jones 2003), and (Liker 2004).
- Students were provided a detailed fabrication drawing, lumber for the top plate, bottom plate and studs, nails, tools, safety glasses, and access to a radial arm saw. A student with power equipment experience was designated to operate the radial arm saw.
- The laboratory instructor used a stopwatch to time the duration to fabricate and assemble the second wall panel.

RESULTS OF LABORATORY SESSION TWO

- After constructing the second wall panel, the class met in the lecture area to discuss what took place. The instructor queried students on improvements they would recommend implementing during laboratory session three. The main recommendations were the need for a second saw and redistribution of students (labour) on the various construction activities.
- Total time to fabricate and assemble the second wall panel was 18 minutes.
- Many of the types of waste, that occurred during construction in laboratory session one, were reduced or eliminated.

LABORATORY SESSION THREE (WEEK 2)

- Prior to construction of the third wall panel, students met with the instructor in the lecture area to discuss wastes observed by the students. Students provided input on how to improve the wall panel construction process. The instructor taught additional lean construction fundamentals prior to fabrication and assembly of the third wall panel.
- One 8'-0" high x 10'-0" long sidewall panel was constructed.
- The following lean construction fundamentals were taught to the students prior to wall panel fabrication and assembly: kaizen with DMAIC (define, measure, analyze, improve, and control) as defined and presented in (George et al. 2005), types of waste to eliminate (over-production, over-processing and transportation) as described by (George 2003), (Womack and Jones 2003), and (Liker 2004).
- Students were provided a detailed fabrication drawing, lumber for the top plate, bottom plate and studs, nails, tools, safety glasses, and access to a radial arm saw and a table saw (added for sessions three and four). Students with power equipment experience were designated to operate the saws.
- The laboratory instructor used a stopwatch to time the duration to fabricate and assemble the third wall panel.

RESULTS OF LABORATORY SESSION THREE

- After constructing the third wall panel, the class met in the lecture area to discuss what took place. The instructor queried students on improvements they would recommend implementing during laboratory session four. The main recommendation was to redistribute students (labour) at construction activities.
- Total time to fabricate and assemble the third wall panel was 11 minutes.
- Some of the types of waste that occurred during construction in laboratory sessions one and two were reduced or eliminated.

LABORATORY SESSION FOUR (WEEK 2)

- Prior to construction of the fourth wall panel, students met with the instructor in the lecture area to discuss wastes observed by the students. Students provided input on how to improve the wall panel construction process. The instructor taught additional lean construction fundamentals prior to fabrication and assembly of the fourth wall panel.
- One 8'-0" high x 10'-0" long sidewall panel was constructed.
- The following lean construction fundamentals were taught to the students prior to wall panel fabrication and assembly: inventory as a type of waste, pull, continuous flow, and the use of kanbans as described by (Womack and Jones 2003), and (Liker 2004).
- Students were provided a detailed fabrication drawing, lumber for the top plate, bottom plate and studs, nails, tools, safety glasses, and access to a radial arm saw

and a table saw. Students with power equipment experience were designated to operate the saws.

- Four kanbans were set up for the following wall panel construction activities (processes): measurement and marking of the studs, measurement and marking of the top and bottom plates, cut plates, and cut studs. An assembly work cell area was designated.
- The lean construction tool pull was initiated by the assembly work cell that was located nearby in an open area of the laboratory space.
- The laboratory instructor used a stopwatch to time the duration to fabricate and assemble the fourth wall panel.

RESULTS OF LABORATORY SESSION FOUR

- After constructing the fourth wall panel, the class met in the lecture area to discuss what took place. Student moral appeared to be high because of the organized construction environment that took place. The instructor queried students on their observations of the pull process and improvements they would recommend if additional wall panels were to be constructed. The main recommendation was shifting students at the various construction activities to provide continuous flow. Some cross-training would be needed.
- Total time to fabricate and assemble the fourth wall panel was six minutes.
- Most of the types of waste that occurred during construction in previous laboratory sessions were reduced or eliminated.
- Continuous flow was not achieved during laboratory session four. Continuous improvement techniques, such as kaizens conducted by students at the laboratory workspace, would eventually produce even cycle times between wall panel fabrication and assembly processes.

Results accomplished by implementing lean construction fundamentals in the laboratories of the CONS 235 Introduction to Construction course of the Construction Management program at Bowling Green State University were significant when compared to previous laboratories teaching traditional construction techniques. The lean construction laboratories provided a good learning environment to expose students to lean construction concepts and fundamentals. Students completed the course with interests in learning more about construction applications and tools of lean construction.

DISCUSSION

Application of a limited number of lean construction fundamentals significantly reduced the time to fabricate wall panels from 26 minutes in laboratory session one to six minutes in laboratory session four. Students got more involved with each successive session. The main outcomes of the laboratory sessions included: an increase in student enthusiasm with each application of lean construction knowledge they learned, students observed organizational improvement of the construction activities, and students felt empowered to make process improvements. This paper documents the outcomes of application of a limited number of lean construction fundamentals and is not presented as a formal research project. A formal research study should be conducted in the CONS 235

Introduction to Construction course to systematically collect and analyze data for reliability and duplicability of the project described.

To enhance lean construction applications at construction jobsites, architectural lean design education and research developments are needed upstream from lean construction. Inclusion of architectural lean design in architectural education will affect building design and construction documents for lean construction. Many opportunities exist to develop lean manufacturing and production principles into architectural lean design and lean construction education areas of knowledge. A few examples would include: new construction techniques for existing building materials such as gypsum wallboard, asphalt shingle roofing, and flooring of various types. Value Stream Mapping, as presented in (Rother and Shook 1999), should be applied as an education tool to study various design and construction processes.

The focus of this paper has been on lean construction and construction education. Construction industry firms will benefit from individuals having knowledge of lean construction fundamentals. Faculty and students of construction, construction technology, and construction management programs can benefit academically and with opportunities for scholarship and research through inclusion of lean construction in their construction education curriculum. Information on lean construction research themes is available at <http://www.iglc.net/themes>. Construction industry firms are becoming aware of the benefits of lean construction and are interested in its implementation.

REFERENCES

- George, M. (2003). *Lean six sigma for service: How to use lean speed and six sigma quality to improve services and transactions*, McGraw-Hill, New York.
- George, M., Rowlands, D., Price, M., and Maxey, J. (2005). *The lean six sigma pocket toolbox: A quick reference guide to nearly 100 tools for improving process quality, speed, and complexity*, McGraw-Hill, New York.
- Liker, J. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*, McGraw-Hill, New York.
- Rother, M. and Shook, J. (1999). *Learning to see: Value stream mapping to add value and eliminate muda*, The Lean Enterprise Institute, Brookline, MA.
- Womack, J. and Jones, D. (2003). *Lean thinking: Banish waste and create wealth in your corporation*, 2nd Ed., Free Press, New York.