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CONSTRUCTION LABOR PRODUCTIVITY BENCHMARKING: A COMPARISON BETWEEN ON-SITE CONSTRUCTION AND PREFABRICATION

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Abstract: Construction labor productivity has been declining over the past sixty years which has caused a decline in overall construction productivity. The traditional way of managing construction project and its delivery have evolved into an inherently inefficient and adversarial process (Koskela 2002) There was always a need to improve how construction materials are constructed and delivered. Lean Construction was introduced to the construction industry in the last century to improve construction productivity through maximizing value and eliminating waste. Minimizing or eliminating project construction waste related to labor is one form of adopting lean thinking which leads to improving labor productivity.

One way to achieve this goal is to *prefabricate* the construction elements off-site, and then deliver it to the site for installation. Prefabrication is a process of assembling building components in a remote location using a production line in a controlled environment and delivering the parts to the construction site. There have been numerous studies comparing prefabricating construction labor productivity to on-site labor productivity. These comparative studies were conducted at industrial or project levels only but not at the task level. This research is to address this gap of knowledge by conducting quantitative statistical analysis of construction labor productivity investigating the effect of prefabrication environment on construction labor productivity by comparing prefabricating wall panels to on-site wall panels installation.

The results of the research will inform the construction firms and contractors with the data time allocated by workers in prefabrication and on-site construction, which will assist them in improving the labor productivity

1. INTRODUCTION

Construction labor productivity has been declining over the past sixty years which has caused a decline in overall construction productivity. Labor Productivity is defined as the ratio of product output to input (labor hours). For example, it can be expressed as how many square feet of concrete slab produced per hours of labor input.

According to the Bureau of Labor Statistics, the construction industry has traditionally been one of the largest industries in the United States. However, since 1960, construction productivity has steadily declined. More than 40% of all projects are either over budget or behind schedule.

According to the Construction Industry Institute (CII), it has been estimated that between 25% and 50% of construction costs are lost to waste and inefficiencies in labor and materials control. Losses are incurred due to errors in information when translating designs into actual construction. Koskela and Vrijhoef (2000) suggest that the old culture of the way we deliver projects is responsible for all projects deficiencies and waste detected in the construction industry. Since construction is a labor-intensive industry, then the weak growth of construction labor productivity has a significant contribution to the decline of the construction industry. However, The fragmentation of a construction site makes it very difficult to measure its performance. A typical site consists of six or more trades or disciplines (Ahmad, 2016). The time which a typical construction worker spends while performing any construction task is divided into three types of direct work, indirect work and idle time: (Allmon et al. (2000). The low rate of labor productivity occurs since construction workers' time spent on site is not fully employed in direct productive tasks. (Dozzi et al.). Prefabrication is a process that complies with lean construction philosophy. This research will investigate the significant improvement of labor productivity when adopting Lean Construction process of fabrication while defining appropriate procedures for measuring construction labor productivity. The purpose of this research is to examine labor productivity in the construction sector by comparing construction labor productivity during construction prefabrication to labor productivity measured during on-site construction activities. The study will provide a quantitative analysis comparing labor productivity (based on square foot per labor hour) of prefabricated wall panels to labor productivity during on-site wall panels construction

2. RESEARCH OBJECTIVE

The issue of the decline in construction labor productivity has been a concern for the construction industry for many years. Park et al. (2005). Numerous researches and studies have been conducted, and data have been collected to investigate and study this issue. Various researches have conducted measuring construction labor productivity at industrial, project and task levels. The focus of this research is identifying factors contributing to the decline in labor productivity in construction sites, by comparing labor productivity of work performed by construction workers while building steel stud walls in a prefabrication shop to those performed on site. This will allow studying the effect of construction site environment on labor productivity which leads to the decline of direct work performed by construction workers. Construction productivity is usually measured at three levels: industrial, project and task level. Huang et al. (2009). The research objective to study construction labor productivity when adopting traditional construction procedure vs. fabrication at task level. The results will provide a better understanding of the factors affecting labor productivity in both environments. This can be implemented by providing quantitative analysis of construction labor productivity (based on labor hour per square foot) by comparing prefabricating wall panels to on-site wall panels installation. The research claims that prefabrication of construction elements such as steel stud walls which are assembled off-site is more productive than constructing the same elements on-site. The reason might be that labor productivity during prefabrication is higher than labor productivity when the task is performed on-site.

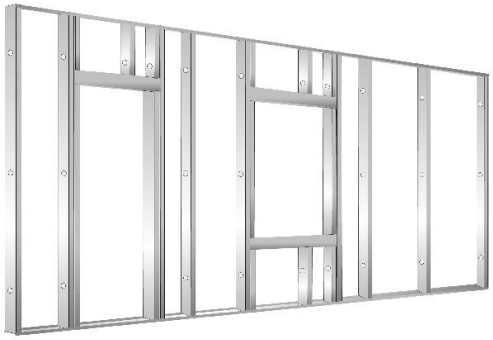

Figure 1: Steel Sud Wall Panel

Previous studies, industrial publications, and contractors' reports have voiced the effectiveness of construction prefabrication compared to traditional construction. However, these studies and researches were implemented at the project and industrial level and not the task level. Therefore, the results lack the comparative data analysis which identifies the direct, indirect and idle times which workers spent in both environments.

The task level comparative analysis provided in this research will inform the construction firms and contractors with the data time allocated by workers in prefabrication and on-site construction, which will assist them in improving the labor productivity and consequently to improve the construction productivity by identifying the deficiency in the construction labor time.

3. EXPERIMENTAL DESIGN AND DATA ANALYSIS

The research begins with an extensive literature review that provides previous published research studies and publications addressing construction labor productivity, construction prefabrication an extensive studying of various statistical analysis methods that can be used as tools to analyze the data collected. The data collection is according to the following procedure:

1. The research data collection consists of observing construction workers assembling steel studs wall panels in a prefabrication shop as well as in a construction site using the work sampling data collection method.
2. The panels constructed are of different sizes. So, the collected data will be synthesized based on Labor hour per square foot, installed for prefabricated wall panels and conventional wall panels from two different projects.
3. Compare saving in labor hour based on wall panels size.
4. Regression analysis: wall panel size vs. labor hour utilized

The research adopts a quantitative experimental design approach in which a random design of the experiment is utilized. The purpose of the study is to conduct a comparative study examining labor productivity as a dependent variable which is affected by two different environments (independent variables or factors). The quantitative design which requires a numerical assessment of the dependent variable is conducted through data collection and data analysis. The collected data is analyzed through statistical tests and, then, the statistical inference is developed. Two groups of construction workers were observed experimenting with two different environments:

1. Group one consists of workers installing steel stud walls using a conventional procedure on site. – control group

2. Group two consists of workers assembling the steel studs' walls in a prefabrication shop and the prefabricated stud walls were then loaded on a truck, transported to the job site, unloaded and then installed. – experimental group

This research aims to measure the effect of the prefabrication environment on labor productivity. A hypothesis test is conducted claiming that labor productivity is improved under prefabrication environment. Labor productivity is quantified as a square foot of produced stud wall per labor hour. The hypothesis of the study claims that the workers can produce more square feet of stud walls per labor hour utilizing prefabrication procedure than adopting conventional on-site process.

To conduct an accurate comparison between the two cases, a conceptual framework is created. The ideal way to ensure comparable groups is through a completely random assignment to either the treatment group (prefabrication) or conventional installation (control) group.

Data were collected from four projects in the Milwaukee and Madison areas. The data collection was conducted through site observation of assembling stud wall panels at the prefabrication shop using the work sampling data method.

The process started by arranging with the prefabrication shop manager to conduct the research. Safety protocol was carefully followed including wearing hardhat and safety glasses. The research observation was conducted by adopting the work sampling method in which assembling time was measured using a stopwatch and recorded on a data sheet. The observation time starts at the beginning of each panel assembling and stops when the panel is completed. Time increment of one minute is recorded. Data were recorded for the time it took to assemble one panel which was converted to a square foot per labor hour.

The data collection stage consists of observation of both: construction sites and a prefabrication shop. During the observation, a stopwatch was used to measure the time it took for a construction worker to complete assembling a stud wall panel in the prefabrication shop or constructing the stud wall panel in the construction site. Data were recorded on a datasheet. Construction plans supplied by the construction contractor were used during data collection and data analysis.

Once the data is collected, the analysis of the data was conducted using computer software such as Excel spreadsheet and SPSS.

3.1 Prefabrication Data Analysis

104 steel stud panels were observed being assembled in the prefabrication shop. The size of panels range is between 3.09 sq. Ft to 166.23 sq.ft. with a mean of 47.92 sq.ft. The lowest productivity is 5.73 sq.ft /hr., while the highest productivity was 80.69 sq.ft/hr. The average of labor productivity was determined to 32.5 sq.ft./hr. and standard deviation of 19.2. It was noted that there is a strong positive correlation between the panel size and the labor productivity.

3.2 On-site Data Analysis

On-site data was collected from three different projects of a total of 114 stud wall panels of different sizes. Installation in all three construction sites was observed, and the time it took to install the panels was recorded. According to a descriptive statistical analysis performed, the size of the installed panels range is between 6.00 sq. ft to 152.2 sq.ft. With a mean of 41.55 sq.ft. The lowest labor productivity is 9.00 sq.ft /hr. while the largest productivity was 71.43 sq.ft/hr. The average of labor productivity was determined to 41.55 sq.ft./hr. and standard deviation of 37.83. Similar to the prefabrication analysis, It was noted that there is a strong positive correlation between the panel size and the labor productivity.

3.3 Comparative Analysis Between Prefabrication and Onsite Labor Productivity

A strong positive correlation between the stud wall panel size and labor productivity for both prefabrication assembly and on-site construction installation was noted. However, when comparing these two correlations in figure 2, we can conclude that the labor productivity in the prefabrication shop for panels sizes which are smaller than 90 sq.ft is lower than the labor productivity for on-site wall panel installation, but higher for all panels of 90 sq.ft or larger. To statistically investigate this fact, a statistical hypothesis test was conducted. Both a parametric t-test and a non-parametric Wilcoxon test were conducted to evaluate if there is a significant difference in the labor productivity between the prefabrication and on-site construction. The independent factor is the location where the work is performed, while labor productivity is the dependent factor. Both tests indicated that in general on-site labor productivity is statically significantly higher than prefabrication labor productivity.

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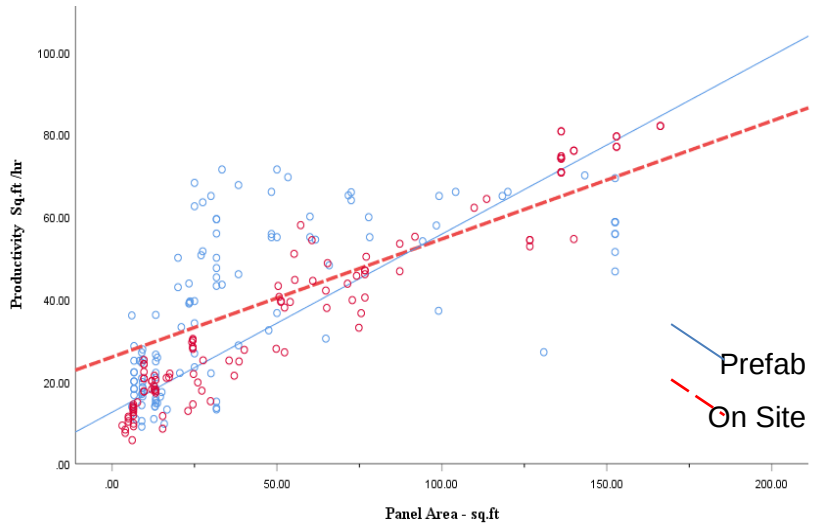

Figure 2: Comparative correlation between Prefabrication and On site (Panel Size vs Labor Productivity)

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