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APPLICATION OF LEAN METHODS FOR PRODUCTIVITY IMPROVEMENT IN STEEL FABRICATION SHOPS: A CASE STUDY

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The objective of this paper is to identify tools and methodologies to increase productivity in commercial steel fabrication shops. The effectiveness of these tools and methodologies has been demonstrated through a case study in a Canadian steel fabrication shop. Three different productivity improvement concepts were identified as suitable for the steel fabrication environment. Lean, Six Sigma, and the Theory of Constraints (TOC). Lean was retained as being the most suitable to steel fabrication due to its low cost, focus on quality, and built in continuous improvement process. In the case study, Lean tools were identified and applied to address three top productivity issues. A baseline was established for existing productivity for a fitting station over a period of two weeks. Selected tools were implemented, and a session was conducted to educate the workers on the new processes and tools. Lastly, the productivity was re-calculated, the results were analyzed, and recommendations were made.

Keywords: Building construction, Six sigma, Theory of constraint, Optimization.

1 INTRODUCTION

There are approximately 2,500 steel fabricators in Canada. Due to expensive field labor and extreme weather on construction sites, shop fabrication is very common in Canada as the production can be carried out in a controlled environment (Ahmad *et al.* 2014). Steel fabrication shops are profit-oriented organizations, hence improving productivity is a major concern since it represents the effective and efficient conversion of resources into marketable products and determines business profitability (Sandbhor and Botre 2014). Since most of the local steel fabricators work with the same suppliers, subcontractors, and local conditions, the playing field is even. Hence, decreasing the amount of time spent on a piece of steel is the most effective way to help the fabricator increase productivity and win the next job. In addition, productivity is one of the most important factors to increase economic growth in a manufacturing environment, which is similar to a steel fabrication environment. Kwiatkowski (2016) concluded that decreasing the amount of time spent on a piece of steel is the most effective way to help the fabricator to increase productivity and win the next job. Because high productivity is one of the keys to financial success of steel fabricators (Kwiatkowski 2016), it is essential for the steel fabricator to understand the application of productivity improvement concepts and tools.

The aim of this research is to identify tools and methodologies to increase productivity in steel fabrication shops. This aim was achieved by implementing the research methodology in five steps. Step 1 involved the systematic identification of tools and techniques, which can be used to improve the productivity in the steel fabrication shop. Step 2 involved creation of fabrication shop process map (used as case study) and establish a current productivity baseline in selected work station. Step 3 involved analysis of selected work station to identify and rank the productivity issues. In this step, selected productivity improvement tools were also implemented. Step 4 involved re-measuring the productivity rate of the station after implementation of productivity improvement tools. Step 5 involved the analysis of productivity improvements, if any, based on collected data and make recommendations.

2 STEEL FABRICATION PROCESS

Construction steel fabrication industry, though it operates in a controlled environment like manufacturing industry, encounters the challenges similar to construction of a facility. For instance, every steel fabrication project is unique. Accordingly, steel fabrication projects manifest the hybrid nature between manufacturing and construction projects. All steel pieces are unique in steel fabrication projects, but they are fabricated in a shop under a controlled environment. A typical process map of a steel fabrication shop is in Figure 1.

Figure 1. Current work flow process for a typical fabrication shop.

2.1 Productivity Measurement Units

According to Hofacker and Gehbauer (2010), hours per ton is the most common measure of steel fabrication productivity due to its simplicity. On the other hand, Song and AbouRizk (2008) argued that there is no consensus in how to measure productivity in steel fabrication environments since different shops will have different means of measuring productivity, which complicates the comparison process. In this research, "hours per ton" and "pieces per day" were retained as productivity measurement units.

2.2 Productivity Improvement Theories

2.2.1 *Theory of constraints (TOC)*

TOC is a methodology for identifying the most important limiting factor that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor. In manufacturing, the constraint is often referred to as "a bottleneck." TOC takes a scientific approach to improvement. It hypothesizes that every complex system, including manufacturing processes, consists of multiple linked activities, one of which acts as a constraint upon the entire system such as the constraint activity is the "weakest link in the chain".

2.2.2 *Six sigma approach*

Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects in any process by driving toward six standard deviations between the mean and the nearest specification limit. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects in any process by driving toward six standard deviations between the mean and the nearest specification limit. The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction.

2.2.3 *Lean Thinking*

Lean Thinking is a set of principles and methodologies for improving cycle times and quality through elimination of waste, sometimes known by its Japanese name of Muda (waste). Lean Thinking allows businesses to distinguish between value-added and non-value-added activities. The objective is to improve cycle times, reduce waste, and increase value to the customer. Lean Thinking has been shown to gain dramatic benefits in organizations. Organizations are able to sustain production levels with half the personnel, improving quality and reducing cycle times from 50 percent to 90 percent (Womack and Jones 1996).

One of the similarities between these improvement theories is that their common first step is to identify the existing processes, but they have their own focus on how to improve those processes. Nave (2002) summarized that the selection of a process improvement methodology is dependent on the culture of the organization. Six Sigma will be a perfect program if the organization values analytical studies and the relationship of data. Lean Thinking is for organizations that values visual change. TOC suits organizations that value a system approach where total participation of all stakeholders is not required. Lean was selected as being the most appropriate to this organization because of its low initial implementation cost, speed of implementation, and overall simplicity.

3 CASE STUDY

The construction steel fabrication industry, though operating in a controlled environment like the manufacturing industry, still encounters challenges similar to the construction industry. For instance, every steel fabrication project is unique.

3.1 Process Mapping and Productivity Baseline

Interviews with the shop foreman revealed that the fitting station was the most time-consuming activity in the shop, where the fitter perform all of the coping, drilling, and fitting tasks. Process of current state was charted (Figure 2) and productivity was measured (Table 1) for two weeks, as baseline measure, by having the fitter fill out a production sheet on a daily basis.

Table 1. Average productivity of a fitting station (before implementation of process improvements).

	Weekly Average Productivity (Hrs/Ton)	**Weekly Average Productivity (Pieces/day)**
Week 1	4.7	9.25
Week 2	5.2	8.75

3.2 Identify and Rank the Productivity Issues

Based on collected data, observations and interviews, research team identified and ranked different productivity issues related to the fitting station. Top issues are listed below:

1. Wait for shared tools.
2. Time spent in searching for parts. Distance from parts storage location.
3. Shop culture: Resistant to change from the foremen to workers.
4. Wait for the crane because it is shared with other stations.

5. Wait for foreman for drawing clarifications.
6. Work Schedule: Dynamic changes in work schedule to meet emerging client needs.
7. Raw material supply delays: due to dynamic schedule
8. Machine or equipment downtime.
9. Lack of welding screens in the shop caused weld flashes, hence slowing the work.

3.3 Select and Implement Productivity Improvement Tools

Team identified and implemented three different lean tools in the steel fabrication shop to address the identified productivity issues namely, optimization of work process, 5S, and Kaizen. It was decided that some steps in the fitting station did not add value and would be better performed by general laborer. This was implemented in optimized work process map, shown in Figure 2.

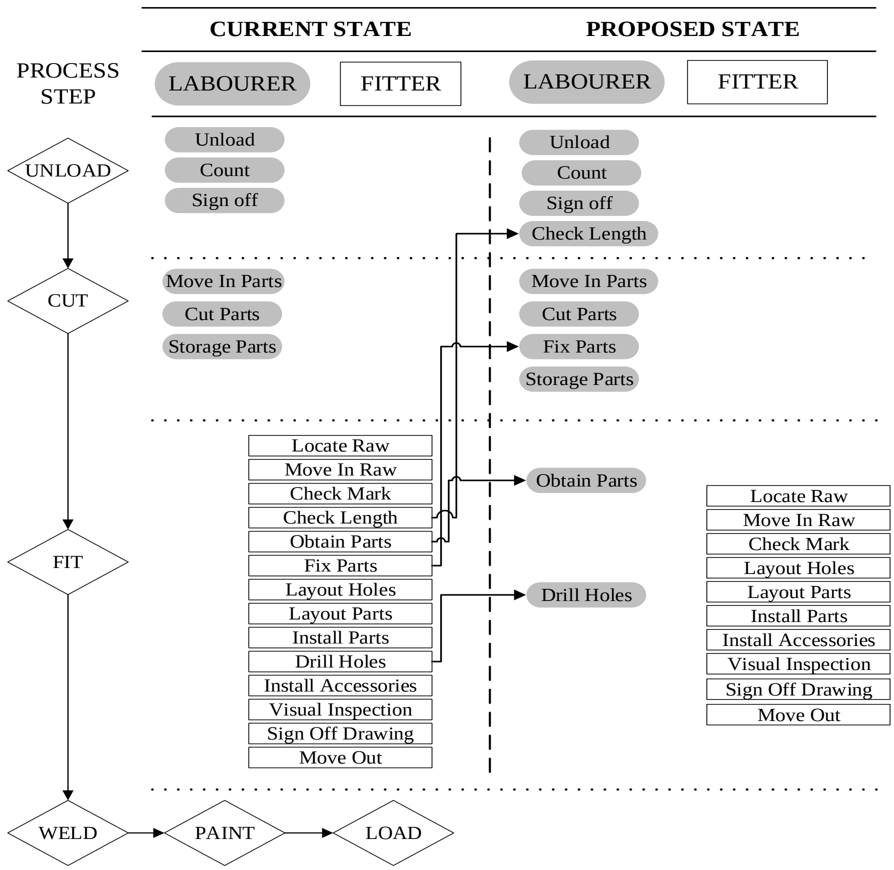

Figure 2. Current and optimized work flow process for Fitting Station.

Second productivity improvement tool used in this research was 5S. It was hypothesized that implementation of 5S will reduce lead times and cycle times of the fitting station, including the time to search the tools. Details of 5S implementation were eliminated due to space constraints.

Third productivity improvement tool used, to improve the culture to accept the change, was Kaizen. To make sure the office and shop employees understand the concept of Kaizen, the research team organized a training session with ten workers from different stations, one project manager, one foreman, and the vice president of operations. Topics of the training session included the origin of continuous improvement, the focus on small improvements the balance between quality and safety, and the continuous productivity improvement of their work.

3.4 Findings

After the implementation of Lean tools and methodologies, the productivity was re-calculated based on 'hours per ton' and 'pieces per day' (Table 2). When comparing the baseline with the new set of productivity data, two conclusions can be made. Firstly, the lean tools were successful in increasing the productivity by either increasing the pieces fitted per day or decreasing the hours spent on each ton of steel. Secondly, when the fitter is working on heavy pieces, the productivity is better harvested as 'hours per ton', but when the fitter is fabricating several light items, 'pieces per day' is more accurate measure.

Table 2. Average productivity of a fitting station (after implementation of process improvements).

	Weekly Average Productivity (Hrs/Ton)	Weekly Average Productivity (Pieces/day)
Week 3	4.1	7.25
Week 4	9.2	12.75

4 CONCLUSION

The Lean Thinking application is the focus of this research. It is recommended to combine its use with the other two improvement theories, Theory of Constraints and Six Sigma. Each of these improvement theories drives toward a common goal but from different perspectives. Combining the use of these theories can provide a larger set of tools that can be applied to each specific productivity improvement issues in a unique fabrication shop. This research validates the fact that lean tools can be used to increase productivity in a steel fabrication shop environment. Further study should be conducted to identify the best productivity measurement unit, which would take complexity of work in consideration. The implementation of lean tools in the stations must be made in a careful manner to not to create new bottlenecks.

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