SUITABILITY AND BENEFITS OF IMPLEMENTING LEAN PRODUCTION ON ROAD WORKS

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ABSTRACT

Lean Production (LP) has been implemented all over the world for the last years, while Lean Construction (LC) just recently began to be implemented regularly in the construction sector. Some companies are currently testing LC methods, but the majority is still unaware of its potential.

The purpose of this work is to assess the applicability and benefits of using Lean construction to road works, by means of the elimination of waste.

This article is based upon a literature review on Lean principles and on case studies in Portuguese roadwork companies.

Value Stream Mapping of the production process on site was carried out in different jobs and companies, in order to assess the generalization of the observations, results obtained and of the solutions proposed.

Finally, the results and conclusions obtained were validated in one road works job site.

A characterization and analysis of the waste types and forms in road works was achieved, and the Lean tools that reduce or eliminate them identified.

This study sets out to identify the main problems and wastes present in road works, and assess how and to what extent LC provides solutions to their correction or elimination, introducing simple modifications in the processes.

KEY WORDS

Lean construction, waste, road works, Value Stream mapping

INTRODUCTION

The construction sector contributes with a significant percentage for the gross domestic product of any country, having a major role in the country's Economy.

Within the last years, developing countries built many roads for the transport of people and commodities, thus originating the creation of many road works companies. The increased number of competitors has been responsible for a relevant reduction in the margins of the jobs awarded. Companies have responded to this menace by attempting cost cuts through the reduction of quality standards. This has proven to be a short sighted option, as owners then enforce their rights during the guaranty period. .

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The present reality of world crisis makes efforts to minimize waste in this sector particularly relevant. However, this is a sector known for its reluctance to change.

This study identifies and analyzes waste in road works and assesses the benefits of adopting and implementing *Lean Construction (LC)* in the elimination of waste, and analyzes how LC can add value to the final product.

The case studies analyzed correspond to road works jobs of several Portuguese road works companies that have operations in Portugal, Central Europe, Eastern Europe, developing African countries and in South America. This range of influence area is important to determine how global the problems and respective measures are.

The research question of this work then becomes: What are the benefits deriving from the application of the *Lean Construction* to road works and how can they be put into practice?

In this article, a literature review was made both on Lean principles, concepts and solutions, and on road works production processes. A research method is then chosen and described. A set of case studies is then analyzed and a typical Value Stream, for this kind of works, is determined. A set of Lean solutions is then determined, based on the assessment of their adequacy to the issues found. These where applied to a case study, and the resulting benefits analyzed. Finally, conclusions were drawn.

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LITERATURE REVIEW

According to Ballard and Howell (1998), there is a significant difference between non stationary construction works and works carried out in an assembly line. A factory comprises an assembly line of machines that define a workflow, whereas in construction the flow is guaranteed by the work rules.

Lean tools can be applied beyond manufacture, and new principles should be derived from Lean philosophy to fight against the major difficulties faced by construction. (Koskela, 2000). In the same work, the author sustains that for a correct implementation of Lean construction it is vital to understand what are the main types of waste to be eliminated from the construction process (7 wastes of *lean thinking*):

- Lack of resources or their readiness, originating delays;
- Unnecessary stages and tasks;
- Unnecessary movement of materials, equipment and people;
- Excess of resources for the accomplishment of a task;
- Material inventories and respective declarations of material conformance;
- Excessive production due to the use of too many resources;
- Production deficiencies, originating correction and consequently the use of more materials and manpower.

Koskela and Bertelsen (2004) suggest a new waste beyond the traditional seven of Lean Thinking. Many tasks are initiated without all the necessary resources or means, leading to low productivity or waiting time. This waste is called "*making-do*".

In the specific field of Road Works, the Portuguese National Authority for Roads and Road Works defines in its standard specifications the following main activities in the construction process of road works (Estradas de Portugal 2009): production of bitumen and its casting, milling, placement of curbs, sidewalks, gutters and drainage channels.

These activities have a repetitive nature and are carried out along an axe. Thus, they have more similarities with assembly line production than most construction works. This might lead to the conclusion that road works would be a well explored field of research for Lean Construction. Surprisingly enough, there was hardly any literature found on this subject.

In one of the few articles found on this subject, Farrar *et al* (2004) defined, in their case study, the following procedure as the most efficient for the implementation of *Lean* philosophy to road works:

- Define the sequence of tasks the production process to be studied
- Select all activities that do not add value;
- Define the durations of the tasks;
- Define the present state;
- Sort the improvement candidates by order of importance for the future state model, focusing the improvement efforts in the processes that have a higher impact on the activities;
- Reduce or eliminate activities that do not add value, starting with the activity that shows the greatest improvement potential;
- Search for practical solutions to improve the material delivery processes; consider the adoption of *JIT*;
- Define the future state;
- Find solutions to improve the production activities;
- Introduce buffers to face the variability of the processes and reduce it.

To create a value flow, the most appropriate and important technique is the value stream mapping (Rother and Shook, 1998)

Abdulmalek & Rajgopal (2007) defined that the methodology to be followed for an effective VSM is:

- Selection of the process one intends to improve;
- Map the current stage of the process, i.e. assess how the tasks are currently being carried out;
- Assess the process, checking the waste and making improvement proposals;
- Mapping the future conditions, a proposal for future development is made to provide answers to a group of efficiency related issues;
- Implementation of the new proposals and measurement of the results obtained for assessment.

Comparing the characteristics of the road works carried out in Portugal with the results obtained from the case studies on Lean Construction previously described in this article, it can be assumed that the benefits of implementing Lean to road works would be very similar.

RESEARCH METHOD

This study is based on a literature review, case study analysis and VSM. The latter was carried according to Abdulmalek and Rajgopal (2007), and Rother and Shook (1998). Six road Works jobs were chosen and observed throughout a time span of seven weeks, in order to define a typical value stream for this kind of works. These six jobs covered, as a whole, all the major activities and production processes indicated in Estradas de Portugal (2009) and aimed at being a representative sample of this kind of works. The value stream obtained was then analyzed and Lean solutions were chosen, based on their suitability to mitigate the problems found.

On a second stage, one of these jobs was selected and studied for 4 weeks. This choice was based on two criteria. Its Value Stream was the most similar to the general one obtained in the previous stage and the most important activities could be observed during the time span of this study. The present state of this job's VSM was then further detailed, and a future state was defined where the Lean solutions chosen were implemented. The results obtained were then analyzed and discussed.

The collection of data and information was made through direct observation, dialogue with the stakeholders and document analysis. A direct observation of the entire work process was made, in order to analyze the current procedures and practices at the organization level, machinery used, work force and workspace. Dialogue was established with the players in the different processes, in order to gather information on the production procedures and their perspective on the way to accomplish the different tasks. Altogether, seven project superintendants, seven foremen and a total of 35 workers intervened in this process. The document analysis was carried out in order to complement the information gathered through direct observation and dialogue.

Before initiating the mapping process, a short presentation on Lean Construction was made to all those who intervened in the process. The mapping of the activities' current stage has been made through observation and analysis of the production process on site, focusing on the existing waste, its impact on the production costs and the factors that inhibited a continuous flow of value. Each activity has been assessed separately, analyzing the role of each of the players. Then, each activity's duration was determined and value adding time distinguished from non value adding time. Proposals were then made to correct deficiencies. Special attention was given to the activities where better results could be achieved and those involving higher costs. Based on the improvement proposals, the future state VSM were then defined, which encompassed only the improvement proposals deemed feasible at short term, where results could be perceived within the duration of this study. Mapping is a technique where the production process can only be visualized as a whole, and it does not guarantee its feasibility (Gonçalves, 2009). Finally, the improvement proposals were implemented. Particular attention was taken on verification and control of the implementation.. Activities' durations were again measured and a comparison was made between activities before and after the implementation of the improvement measures.

DATA ANALYSIS AND DISCUSSION

Based on the observation and comparison of the six jobs studied, it was concluded that the major problems identified were common to all of them. In this section the major activities defined in Estradas de Portugal (2009) will be listed and the problems found in their production process indicated separately. Finally, the Lean solutions chosen will be materialized in improvement measures and their implementation described. The results obtained will then be assessed and discussed.

BITUMEN PRODUCTION

Excessive stocks of aggregates were observed, and they were kept in an unorderly manner.

On an irregular basis, the quality control lab tests to the bitumen mix had insufficient results, which caused its rejection. This was found to be due to wrong dosages of aggregates in the mix.

Proposals

1. Implementation of *JIT* by reducing the quantity of material in stock from enough to 4 workdays to enough to 2 workdays. This shall be used in conjunction with *Kanban,* in order to clearly determine stock levels and the exact time when a new supply is needed.
2. Implementation of 5S so that the materials are kept in an orderly manner, avoiding unnecessary work for loader shuffle.
3. Use of *Kaizen*, in order to have a very strict control on the quality of the material produced. If the bitumen is not in proper conditions, the surface shall have to be scrapped and new bitumen will need to be cast upon (rework).

Implementation analysis

In order to fully implement and assess the measures proposed, the already existing stock needed to have been totally used. This condition could not be met; hence it was not possible to implement these proposals.

PAVEMENT – WORK FRONT

An excessive number of trucks was noticed. This was due to the fact that they waited for a very long time to unload. Also some of trucks used were not adequate. Contractors used semi-trailers, which had difficulties in the maneuvering and held up work.

Often there was no collaboration between the driver of the paving machine and the operator of the opening of the pavement system.

These works are dependent of the weather conditions and have to be stopped when it starts raining.

Proposals

1. Implementation of the *Total Productive Maintenance* (TPM), in order to control the maintenance of the equipment. The type of machinery used for paving is complex and have many tools and systems that need to be in good condition. This requires substantial preventive maintenance
2. Strict planning needs to be made, in order to ensure that this type of works is made during dry weather periods. Still, since weather conditions are often unpredictable, efforts need to be made in order to accommodate short noticed schedule changes due to unforeseen rainfall.
3. Collaboration between all the players involved needs to be ensured and controlled, in order to guarantee a continuous workflow.

Implementation analysis

On a daily basis**,** before the beginning of works, the paving machine was lubricated, and wear and tear parts were checked. When deficiencies were detected, they were immediately reported to the personnel in charge of repairing the machinery. As a result of this measure, the paving machine stopped fewer times due to minor failures or lack of calibration.

The cylinders were also checked on a daily basis. At the end of a day the operator reported whether it would be necessary to refill the water deposits. This measure eliminated waiting times in the following day.

The most prevalent types of trucks used continued to be semi trailers and four axes trucks. Semi trailers were mostly used when the milling central was located far from the work front.

It was noticed that sometimes quality levels were compromised as a reaction to unexpected weather conditions. Confronted with unexpected rain, workers tend to keep on the paving works, in order to avoid wasting the bitumen mix already loaded onto the trucks. This causes quality issues on the short term.

The measures implemented resulted in a production increase of approximately 10%, going from 40 Ton / hour to 44 Ton / hour, considering a pavement width of 3.50m and a thickness of 0.07m.

In financial terms, it was possible to increase the profits in approximately 5.4%, depending on the material used and on the width and thickness of the surface that is being paved.

MILLING

In the milling process the milled thickness must be controlled, in order to guarantee that the line previously marked in the pavement is not exceeded.

A milling cutter has a conveyor that can dispose the milled materials to a truck straight away. Thus, the remaining material that needs to be clean is relatively small. However, if the milled material is not disposed because the truck is not available, the cleaning process will take more time.

Proposals

1. During the milling process, the thickness to mill must be continuously monitored, in order to avoid over milling. *TPM* should be implemented to ensure that the milling cutter works with accuracy and in proper conditions.
2. Implementation of *JIT* so that a task that is being executed wrongly may be immediately interrupted and properly corrected. One of the wastes defined by Koskela (2000) is *making-do*. This is what happens in this case, since activities are often started without having all the necessary means available.

Implementation analysis

Continuous monitoring and adequate maintenance of the cutter prevented over milling, which would cause extra costs due to unnecessary over thickness in the asphalt layer, and under milling, which would originate rework.
Works were never initiated without having all the necessary means in place to their correct accomplishment. A continuous production flow was achieved.
This activity had an increase in productivity of around 17%, from 17 min / m^2 to approximately 14 min and 30 seconds / m^2, for a constant mill thickness of 0.05 m.
In financial terms, considering the production increase obtained and the expenses incurred, the final result is a decrease in the costs of approximately 4.3%.

PLACEMENT OF CURBS

A lack of coordination between the paving team and that one that places the curbs was observed; sometimes both tasks were executed at the same time, causing one of the tasks has to stop.

The materials for the curb works were placed inadequately. This caused other works in the same front to be slowed down, or it caused unnecessary long transportation by the workers, since they were kept too far front the work front.

Proposals

1. Implementation of 5 S so that the materials are placed in an organized manner and in places where they do not hold up other works. Special attention must be given to *Seiton*, to assure that all the elements are always within reach of the workers.

2. Dialogue and planning of the tasks involved in the work front, in order to achieve coordination and complementarities among all players.

Implementation analysis

The first task to be carried out in this type of works is the preparation of the surface. Thus, the truck carrying concrete can unload while casting in place. Thus, it will only be necessary to level the surface in order to finish these works.
The curbstones brought in were placed in piles of 4 to 8 elements at regular distances along the entire road.
For circumstantial reasons, it was not possible to create a collaborative team spirit among the task players.
The production rate of this work front increased around 18%, the time to complete the task was reduced from 1 hour and 44 minutes / m to 1 hour and 28 minutes / m.

This way, it was possible to achieve a 5.5% decrease in the cost of this task.

SIDEWALKS

These works were seldom a continuous process, planning had not been sufficiently detailed to guarantee that big enough surfaces were available to allow the continuous use of a concrete truck. . As a result, trucks headed out to the work front even when the surface is not ready to receive the necessary concrete. This creates problems with the concrete pump, which sometimes is not properly secured due to unleveled surface, causing damage to the equipment and, in some cases, ruptures.

Proposals

1. Implementation of a pull production philosophy, based on *JIT* and *kaizen* that could guarantee that concrete would only be unloaded when it is really necessary. Thus, concrete trucks were sent to the work front only when conditions were met for a continuous unload process.
2. The conditions of the surface must be constantly checked, so that the concrete could be poured correctly.
3. Prior planning of works had to be made, so that they could be carried out continuously, without unnecessary interruptions.

Implementation analysis

It was possible to achieve an improvement in resource utilization, since the concrete trucks were not held up at the work fronts while waiting to unload. Thus, they, could be used in other tasks.

Through systematic checking of the conditions of the terrain surface before pouring the concrete, land voids that previously caused damage or even destruction of the pumps were prevented.

A 3% cost decrease was achieved in this task.

GUTTERS AND DRAINAGE CHANNELS

It was sometimes noticed that that gutters and drainage channels had to be rebuilt because they had been placed at the wrong level or had improper inclination. These mistakes occur due to lack of monitoring of the activity by the individuals in charge and because there is no coordination between those and the paving works.

Proposals

1. Enabling the implementation of *JIT* through a strict monitoring of the activity.
2. Close coordination with the paving works, so that both could work regarding pavement elevation and inclination.

Implementation analysis

A greater control of the final level of the gutters and drainage channels was achieved by entrusting the supervision of the task to the individual in charge of the paving work front. This further resulted in a closer coordination between these works and the paving works.

It was possible to reduce the production time from 5 hours and 15 min / piece to 4 hours and 50 min / piece, which resulted in a production increase in this works of around 9%.

Rework was also significantly reduced, and a cost reduction of 4% was achieved.

CONCLUSIONS

This study demonstrates that *Lean* construction applied to road works is able to reduce the existing waste by means of relatively small changes in the way each activity is carried out. All the modifications introduced resulted from an analysis of the VSM, which revealed to be an easy and effective to apply to Road Works, with objective results. The data supplied by this technique must be then dealt with through the utilization of Lean tools and techniques. For this purpose, *JIT*, *5S*, *TPM* and *Kanban* have shown to be adequate and set the basis for the improvements achieved. It should be added that Kaizen, materialized through planning and control, also played an important role in the results obtained.

JIT and *Kanban* implementation led to a reduction to half the amount of material in stock, consequently decreasing to half the capital held up in stocks. In addition, *JIT* was used to liberate spaces in the work fronts by guaranteeing the materials are only delivered to them when they are actually necessary, and as a mean to control the activity.

The implementation of 5S in specific activities organized the work front and resulted in the occupation of less space, an increase of productivity and safety, and it minimized interferences between the placement of materials and the execution of other works.

The implementation of *TPM* tool enabled a preventive and regular maintenance of all the equipment. This led to a decrease in the number of equipment malfunctions, resulting in production increase due to the correct functioning of the equipment.

The prevalent mindset in the company was adjusted to Kaizen, and all activities became subject to a continuous improvement process that. This lead to a final product with more value added.

This work portrayed the main problems and wastes associated to road works from a practical, work front perspective. An analysis and selection of the most adequate Lean tools and principles was made, in order to correct them by introducing simple and easy to achieve changes to the production processes.

This study finally points out the importance that control and continuous improvement of the activities have in guaranteeing that the results obtained may prevail throughout time.

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