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EXTENDED ABSTRACT

APPLICATION OF LEAN TECHNIQUES IN THE SCHEDULING OF CONSTRUCTION PROJECTS

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1. INTRODUCTION

Despite being an old industry with its own methods, construction nowadays sees itself facing ever more demanding clients, who look for more varied products faster and with greater quality without it involving too great an increase in costs, and also the projects are more dynamic and complex. From here emerges the need to implement innovations which improve the industry's performance.

In the last few years, the Lean methodology, with an increasing number of advocates, has been introduced, having as its main objective to obtain greater quality through the elimination of waste, which implies continuous improvement, which is to say, to do more with less.

In this work a model was developed for the improvement of performance based on Lean tools which can be implemented in the execution stage in the area of Planning and Production Control, it being considered that the poor performance of construction (deadlines not being met and low quality) is, in a great deal, related to the bad practices of this area.

2. LITERATURE REVIEW

Due to the increased competitiveness in the construction sector, the need to solve the problems which lead to poor performance, through the introduction of new management techniques has arisen. Several solutions for these chronic problems have been proposed, most of them from manufacturing – such as pre-manufacturing and industrialization. After the revolution provoked by Lean Production in manufacturing, the philosophy was introduced in the construction industry.

Lean Construction is a management philosophy which bases itself on designing the product and the construction process together, to avoid design errors/omissions which raise possibility issues during execution. It's a philosophy where all intervenients participate in the process, the managers are the first to plan (processes and stages) and the foremen and labourers the last (operations), unlike the traditional method of management.

One of the fundamental concepts of Lean Thinking is that of continuous flow. The application of this concept to construction is particularly difficult, the absence of a flow is evident: construction production systems are characterized by a number of interruptions, creating several types of waste and poor use of resources.

To achieve a continuous flow a well prepared planning is necessary, as well as total cooperation by all intervenients, but also other factors related to the complexity of the construction industry which don't allow to follow planning strictly, such as: changes in the work conditions, issues with supplies, design corrections, weather conditions, etc. The existence of delays creates pressures in those involved to accelerate production, increasing the necessary

resources, creating buffers to cover for variability and waste inherent to the construction process.

The success of the implementation of the Lean Construction concepts, principles and tools requires all intervenients to be involved. According to Alves *et al* (2009), different initiatives should be put into place to keep the participants motivated during the change from the conventional planning and control methods to those proposed by Lean Construction. Before changing to a Lean system, the traditional model must be challenged and the gains related to the implementation of the new system should be visible to all (Alves *et al*, 2009).

According to Howell (1999), in Lean Construction planning and control are two faces of the same coin, which flips sides during the project. Planning defines the criteria to achieve success and elaborates strategies to attain the objectives, and production control has as objective the insurance that planning is observed and triggers the learning and re-planning process.

Due to the complexity of construction projects and the variability of the processes which constitute them, there is a need to divide planning into different hierarchical levels. Ballard (2000) suggests that planning should be prepared on three general levels: long term or initial planning, midterm or lookahead planning, and short term or commitment planning. The first level may be sub-divided into two: general planning and stage planning. The general plan (*master pull schedule*) is a complete calendarisation of the project. The stage plans (*phase schedules*) are elaborated by the team which manages the work in the respective phase, have greater detail and should have a foresight of at least six weeks respective to the first activity.

Table 1 presents a summary of the existing methods for the various decision levels of a project.

Table 1 – Decision levels and planning methods

Decision Level	Strategic	Tactical	Operational
Planning type	General	Lookahead	Commitment
Method	CPM	CPM, Critical Chain, LB, LPS	LPS

The Last Planner System was developed in the United States by Ballard and Howell in the 90's. It's a tool for the control of production in construction sites. Throughout the years it has grown into the most popular tool of Lean Construction, due to the success attained in a number of case studies of its implementation.

According to Ballard (2000), the LPS is a mechanism which transform what *should* be done into what *can* be done, allowing to create an inventory of work ready to be done and from which the *Weekly Work Plans* (WWP) are defined. The attribution of work in the WWP implies a commitment of all those involved in the work that *will* be performed.

The most recognized LPS performance indicator is the PPC, which is the ratio between the number of concluded activities and the number of planned activities, presented in the form of

percentage. A high PPC indicates that more work is being completed with the available resources, as well as a greater reliability in the conduction of that activity. For the PPC, an activity is either totally completed or not.

According to Ballard (2000) the analysis of the frequency of causes for the non conclusion of planned activities is an important indicator, along with the PPC which allows for perfecting and improvement for future packages of work.

The main difficulties for the implementation of the LPS were described by Kaalsas *et al* (2009):

- The need for all those involved to ensure a steady flow of workers;
- Creating work packages with associated productivities;
- Consider the subcontractors plans in the LPS;
- Improve the connection between production planning and midterm planning;
- Need to complement the PPC with other flow indicators.

It can be stated that, according to the broadened concept of pull production, Last Planner creates mechanisms to pull activities of production and of supply of resources, on the short and midterm levels, respectively.

According to Leigard and Pesonen (2010) the core idea of LPS is to get people in the project collaborate at a new level of intensity and develop a genuine eagerness to solve root causes of re-occurring problems in production. This is not achieved unless implementation is capable of changing people‘s deepest ways of working and thinking. Because of this reason, use of LPS will not grow organically unless a great amount of mental coaching and motivating is given in advance to the company‘s employees at all levels of the hierarchy.

According to Seppänen and Aalto (2005), the combination of the Last Planner System with a planning based on location, such as the Line of Balance (LB), allows to evaluate the consequences of the deviations from the Weekly Work Plan (WWP) in the general plan, thus allowing for a better control of the production system, promoting a more proactive management. The Line of Balance (LB) is a planning technique, created in the 40’s, applicable to repetitive and sequential projects (construction of roads and buildings with several floors for example).

The planning of activities with the LB allows to know for how long that activity will occupy a given location. In this kind of location based planning, it’s necessary to have a way to evaluate production performance (Luong and Ohsato, 2009).

The use of the LB in real projects implies that the greater part of the benefits are lost in the implementation stage due to varying productivities and inadequate control mechanisms on site. The LPS reduces variability by ensuring the quality of the attributed work packages, allowing for learning during the project’s conduction and that the decisions are taken with commitment from the part of the persons which are going to perform the work, and close to the time of its realization (Ballard, 2000). The LPS is criticized for not considering productivities and for it

being easier to continue a work than to initiate it after an interruption; even though it can achieve great results in a week, it can also destroy the pre-requisites for the following weeks (Seppänen and Kenley, 2005).

The general planning made with the LB imposes a flow of production and productivity rates on a macro level, while the planning of activities, despite being limited by the former, made with the LPS it is used to ensure a continuous flow for each activity (Seppänen and Aalto, 2005).

The combination of these two methods allows to define more realistic objectives, making planning more reliable. To only monitor and control planning on the long term isn't sufficient for it's important to involve subcontractors in the planning process, so that they commit with respect to the set objectives.

The development of a hybrid model has a great potential to improve the performance of a construction site.

3. CASE STUDY

A study was performed about the management strategies and administrative practices currently used in the construction sector in Portugal, through the introduction of the investigator in a construction company. Two case studies were selected, with different characteristics, but both with a high level of subcontracting.

To better evaluate the opinions of the intervenients in the production process, closed response opinion surveys were conducted.

By analyzing data from the first part of the opinion survey it was concluded that although the results show that keeping up to date the planning is a recognized key to success for a production system there is no commitment in developing it.

In the opinion of respondents would be beneficial to the production system to motivate subcontractors to participate more actively in the production system through the preparation of updated schedules and commitment to an weekly plan.

It was concluded that most stakeholders in the production system consider a planning method based on the location is appropriate for solving the problem of reconciling the various subcontractors in space and time, which is the culprit of certain forms of waste on site.

Regarding the possibility of introduction of innovative methods in construction industry the areas which in the opinion of respondents has a better chance of implementation are the areas related to communication between the various parties (subcontractors, owner and general contractor work) and planning.

Based on the survey results, where the respondents highlighted the main problems of the production system, a model of improvement of the existing planning and production control processes was idealized.

4. MODEL

This model is based on the use of two Lean tools, the Line of Balance and the Last Planner System. It is divided into two fundamental parts, the first being dedicated to the definition of four levels of planning: Long Term Plan, Stage Plan, Execution Plan and finally Weekly Plan – the first prepared resorting to the Gantt chart, the second to the LB and the last two levels belong to the LPS method. The second part of the model consists of production control through the analysis of indicators – this allows to evaluate planning performance and its reliability.

In the case study, the Long Term Plan was the initial work plan of the project, prepared with the MS Project software, using the CPM method. In this plan the deadlines of big stages are defined, and it is normally used for the establishment of a payment plan to suppliers.

The stage plan is made based on the dates defined in the general plan. In the case study two stage plans were prepared. The first was the Terrain, Foundations and Structure Plan. This was made on MS Project. The second stage plan was the finishes one. In the proposed model, this level of planning should be prepared using the Line of Balance technique. In this technique a continuous and reliable flow of work is expected. The important dates of start and end of the phase being planned are extracted from the initial work plan.

When preparing a plan based on location, such as the Line of Balance, the main idea is to establish a production rhythm as realistic as possible based on the quantities, resource availability and productivity. This type of consideration differs from the traditional way which consists on attributing a duration for a determined activity without considering the context. Should information about the teams' productivities for certain activities not be available, this will need to be estimated based on the experience and knowledge of the personnel responsible for planning.

The Line of Balance can be prepared resorting to specialized software such as Vico Control Software or with MS Excel. When opting for the latter option – since it is least expensive, there is a limitation, for one of the advantages of the LB is to be able to test alternative scenarios. When resorting to MS Excel, it becomes more difficult to take advantage of this, and also more troublesome to perform updates.

The next level of planning is the midterm one, defined in the Last Planner System's method, and requires a constraints analysis. In this horizon, the managers should be involved to ensure the availability of the means to achieve the objectives of the Long Term Plan.

It is prepared to ensure that the manager may identify and select from the Long Term Plan the activities to be executed in the following weeks. It is up to the manager to take the necessary measures for those activities to be executed in the planned time and conduct the reprogramming of those activities which are not ready to be conducted, so as to impact as little as possible the project's conclusion date. This procedure allows to anticipate the problems protecting the inferior level of uncertainty planning.

In the developed model the use of analysis control charts and removal of constraints are proposed. These must be filled in the weekly meetings which are conducted on site, thus making the control over the planning's current situation easier.

The last level is the day-to-day planning, and intends to be the direct interface with the productive system. It is a plan with a one week time horizon, and it is an operational plan.

In this stage emphasis is given to the resolution of problems and to real time controlling– it is a commitment plan. The commitment of all those responsible for the conduction of the works is fundamental for an effective implementation. This commitment must occur during the weekly meetings, when the work packages are negotiated based on the current stage of execution of the project, and on the teams' execution capacities.

The type of control proposed by the developed model intends to introduce a component of scientific measurement not very common in the construction industry. The need for this kind of control arises from the need to have the greatest knowledge possible about the current situation, so that the decision about the sequence of future activities is as realistic as possible.

One of the main indicators to be measured is the PPC. This indicator is obtained via the ratio between the completed work packages and the planned work packages for that week. It is important to mention that in the LPS the concept of activities 90% completed does not exist – the activities are either completed or not. In the case of an activity which is 95% completed, it is considered that it is a non executed activity. The measurement of the PPC is done weekly, based on the planned activities from the weekly plan; control is done weekly, before the meeting.

The PPC is an indicator of compliance with the planned activities, but doesn't supply much information about productivity. Productivity can be calculated resorting to the following expression:

$$P = \frac{No.of\ workers\ \times work's\ duration}{work\ quantity}$$

Knowing productivity is important in that it allows to evaluate if the project is advancing with the planned rhythm or if any type of adjustment is necessary. To do an analysis between planned productivity, which may be taken from the Balance Line (Long Term Planning) and the real productivity is relevant to establish a baseline for future projects. In this model, the creation of a

website is proposed, where companies of the construction sector may share information about the productivities of certain activities, thus making planning more realistic on the higher levels.

In the proposed model, production control also included the analysis of the causes of non conclusion of the activities. The verification of the state of the planned activities in the weekly map should include the investigation of the causes should the activity not be concluded.

In the end of each week, before the conduction of the weekly meeting, a production control report should be prepared with the information relative to the PPC, productivity, and causes for the non conclusion of activities.

A planning and production control routine must be established on site, or new aspects should be introduced in the existing routine. In Figure 1 a cycle for the implementation of the model (short term planning level), based on the routine of the case study, is proposed.

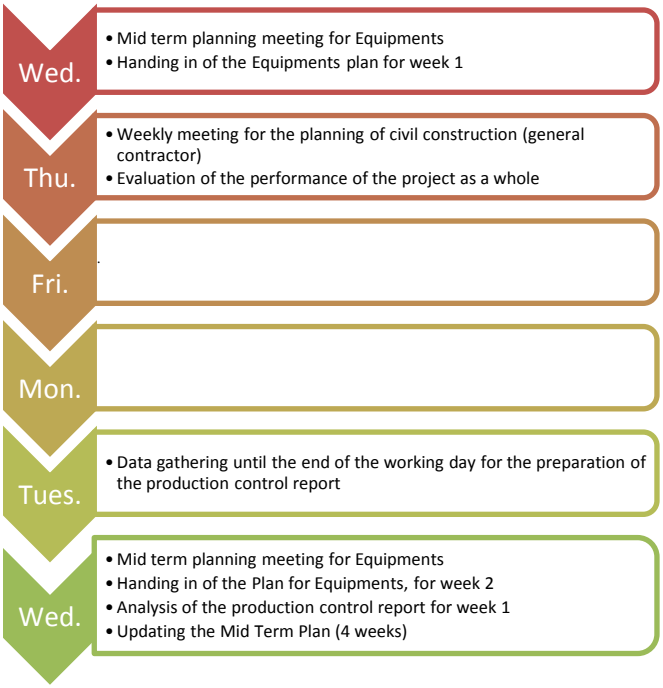

Figure 1 – Weekly production control and planning cycle

5. CONCLUSIONS

It was concluded, with this work, that the case studies present a great potential for the implementation of the developed model for the level of work packages which are repeated is high, and both were large scale projects, where the benefits would be more visible.

So as to ensure the success of the implementation, this should be started while still in the negotiation stage with the client, in preparing the general planning.

The proposed model of implementation of Lean techniques has as objective to improve on site planning and production control, increase the stability of the management system and reduce waste and variability of the management system.

In summary, the main objectives are the model are:

- To help in the execution of a more effective planning;
- To evaluate the influence of delays in the general planning;
- To identify the causes of non compliance of objectives, so that they may be eliminated;
- To promote the creation of a steady production flow;
- To evaluate the productivity of the activities;
- To meet the execution deadlines and if possible shorten them;
- To promote a collaboration culture among the diverse intervenients.

It was also concluded, throughout this dissertation, that the access to performance indicators, such as PPC and productivity, may make easier the management of subcontracts, which, considering the high level of subcontracting of the construction projects may be very useful.

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