PRODUCTION MANAGEMENT IN CONSTRUCTION REQUIREMENTS AND METHODS

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Abstract: Trying to identify why Production Management in construction so often fails, the aim of this paper is to explore the most common reasons why this happens. To link the findings with practice this paper is based on an observatory case study made in a UK construction company. After that, the Production Management requirements are presented as well as the mostly used conventional methods in construction. Among them are the CPM, Line-of-Balance, Critical Chain, and the Last Planner System. The discussion compares them with the production management requirements previously presented. Finally, conclusions are made about Production Management in construction needs and future research expectations.

Keywords: Methods, Production Management, Requirements.

1. INTRODUCTION

Production Management methods can be responsible for many failings in construction projects (Kenley, 2004). Apart from a few cases of new methods developed, the construction industry has been used to planning and controls not complete satisfactory tools and techniques. The majority of these methods are based on bygone principles or they were adapted from the manufacturing industry to be suitable to construction. As a consequence they are not able to cover all the Production Management needs in construction. From this background the goal of this paper is define the requirements of Production Management as well as to evaluate the major methods that have been used in practice.

2. A CASE STUDY IN AN UK CONSTRUCTION INDUSTRY

The authors have been involved in a partnership to conduct a case study with a UK construction company during the first semester of this year. The project covered a refurbishment of an old mill and its transformation into a residential block as well as facilities for car parking spaces and accessibility. The academic objective of this case study was to sharpen the author's PhD research problem and identify construction industry needs. The data collection was made by direct observation where the company Production Management System could be analysed and its application in practice.

The company production system is explained in three guidance booklets to provide standard forms for information flow and consequently data for decision-making at all hierarchical levels of the company. These guidance booklets have good details regarding the way that managers should control the production and also what they have to report to their supervisor.

In practice what could be noticed is that the bureaucracy between the several managerial levels made the company inflexible. As a result of this inflexibility we can pinpoint the length of time for decision-making and the amount of waste regarding human effort and time in the construction processes.

Waste identified in the task analyses includes:

- Waiting time,
- Inadequate equipment,
- Over-manning,
- Rework,
- Unnecessary transport,
- No industrialization of process (pre-fabricated),
- Inadequate materials management,
- Discontinuous task execution.

The majority of these types of wastes is not unique and can be found as common problems around the world in the construction industry. Among the reasons for these wastes, common issues as well as situation specific issues could be observed:

- A push type of production control, conventionally used in construction, has overall in itself been found to lead to unpredictability and loss of productivity – indications of this could be perceived also in this case study,
- Split responsibility for planning,
- Complexity,
- Sub-contracted workforce hinders a continuous improvement programme,
- No commitment by all stakeholders in the scheduling phase,
- Buying department was not linked by any one of the plans,
- IT missing.

Thus, even in a company where, at first sight, production management seems to be orderly structured and implemented, the performance of production management is poor. From this background, it is pertinent to challenge the ends and means of production management.

3. PRODUCTION MANAGEMENT REQUIREMENTS

The objective of the requirements in Production Management is to supply the decision maker with information about agreed levels of utilization of materials, machines, and labour. Furthermore, it is achieved by controlling: quality, speed, dependability, flexibility, and cost (Henrich & Koskela, 2005).

Virtually all managers want on-time delivery, minimal work in process, short customer lead time, and maximum utilization of resources. Unfortunately, these goals are in conflict. It is much easier to finish jobs on time if resource utilization is low. Customer lead times can be made essentially zero if an enormous inventory is maintained. And so on. The goal of production scheduling is to strike a profitable balance among these conflicting objectives (Hopp & Spearman, 2001).

Koskela and Ballard (2003) summarized the requirements of the Production System in construction as follow:

A. A production system in construction should be designed to realize at least the following requirements: delivering the product, minimizing waste and maximizing value (lean construction).
B. All managerial functions: design, operation and improvement, must contribute to the realization of these requirements.
C. The generic peculiarities of construction, as well as the situation wise characteristics, must be taken into account in the realization of these requirements.
D. All parts and aspects of the production system must be integrated: synergies must be utilized, and contradicting issues must be balanced.

Further we will use these requirements to base a comparison among the production management methods in construction.

4. PRODUCTION MANAGEMENT METHODS

There are different kinds and varieties of production management methods; the most common of which are introduced and analyzed in the following sections.

Critical Path Method – CPM

The Critical Path Method (CPM) basically developed as an extension of the Gantt/Bar chart, to determine mathematically, the sequence of activities that would need to be followed to allow the project to finish in the minimum time possible. First developed by DuPont and Remington Rand (UNIVAC) around 1957 (Kelley & Walker, 1959), CPM networks not only included activity dependencies, but also provided each activity with a unique numerical identifier and an estimate of the activity's duration. Apart from determining which sequence of activities was 'critical' for the timely completion of a project, it was also possible to calculate the amount of 'float' that could be used before a delay to the start of a 'non-critical' activity impacted on the overall programme – considered to be very important on large and complicated projects. A variation of the CPM approach is the Programme Evaluation and Review Technique (PERT), which tries to allow for activity duration uncertainty, by using best, worst and most likely duration assessments to calculate each activity's approximate duration.

Whilst the majority of CPM networks are displayed in the Activity on Arrow (AoA) format, it is also possible to use the Activity on Node (AoN) or Precedence format to display a programme. However, the AoA method is often preferred due to the way the length of an activity is generally related to it duration on a project time scale.
Major benefits of using the CPM approach include providing a disciplined method for planning construction, showing the logic and construction methodology being used, showing the interdependencies between both critical and non critical activities and assessing the impact that various resource options might have on the project (Kelley & Walker, 1959; Jaafari, 1984).

Over the years, as CPM became more popular as a method of Project Management, the software that was developed to analyse the data has became more and more sophisticated, allowing for full project monitoring, activity splitting, resource levelling, cost control and variety of other functions to be included.

The Line-of-Balance – LOB

The Line-of-Balance (LOB) was originally derived from the manufacturing industry and was developed by the U.S. Navy Department in 1942 for the programming and controlling of repetitive or one-off projects. It was later developed by Nation Building Agency (in UK) for repetitive housing projects, where a resource-oriented scheduling tool – that considered resources as the starting point – was considered to be more appropriate and realistic than one that was more activity-dominated. This method was later adapted to planning and project control (Lumsden, 1968), where resource productivity is considered to be of particular importance.

Line-of-Balance proposes that activities should be planned within their production rhythms, in other words, the number of units that a crew can produce in a determined time unit. These rhythms are shown in a graph 'time x units' and it can represent the real production of units. The LOB helps the foreman of a production line, at anytime; to observe the progress of each activity by its ability to maintain a set rate of productivity. In many phases of its application many decisions have to be taken by the foreman such as: level of detachment in activities planning, crew size, production expected and achieved, production rhythm and learning, that result in the number of crew simultaneously on the site, their position/location; the direction of production and technologies available or able to be used (Mendes, 1999).

A common characteristic of Line-of-Balance techniques is the typical unit network. LOB is a variation of linear scheduling methods that allows the balancing of operations such that each activity is seen as being continuously performed, even though the work is carried out in various locations. The major benefit of the LOB methodology is that it provides production rate and duration information in the form of an easily interpreted graphics format (Figure 2, Arditi *et al.*, 2002).

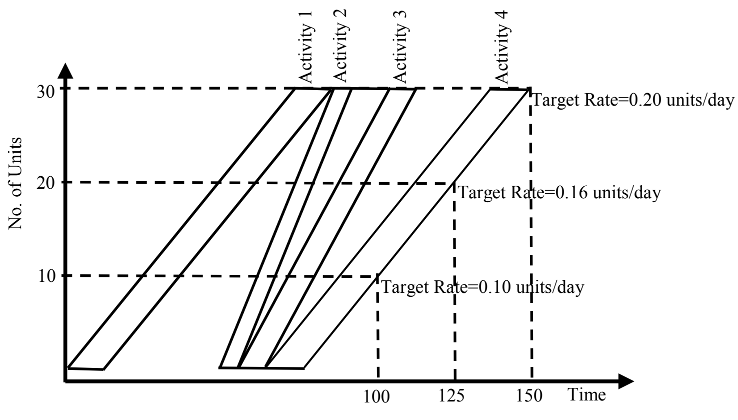

Figure 2. Line-of-Balance and production rate (Figure 1 in Arditi et al. 2002)

Critical Chain

The basic idea underlying Critical Chain Project Management (CCPM) derives from the theory of constraints (TOC), developed by Goldratt (1997). TOC asserts that goal achievement for any system is limited by a constraint.

Goldratt (1997) took this simple idea into the world of production with five focusing steps for system improvement:

a. *Identify* the constraint;
b. *Exploit* the constraint (do whatever is necessary to ensure the constraint works at full capacity);
c. *Subordinate* everything else to the constraint (eliminate interferences with exploiting the constraint to achieve system throughput);
d. *Elevate* the constraint (get more of the constraint);
e. Do not let *inertia* keep you from doing the cycle again.

In production planning terms the system's constraint is the bottleneck. Goldratt (1997) argues that the main reason for project overrun is because of the misuse of the safety time created within the estimated times for each activity. The tendency is overestimate the times to give a reasonable degree of certainty of completion. The approach of TOC is to relocate the safety times in strategic positions. Time estimates may be reduced, but safety buffers of time at the end of the project are added. This will have the effect of reducing the length of the critical path.

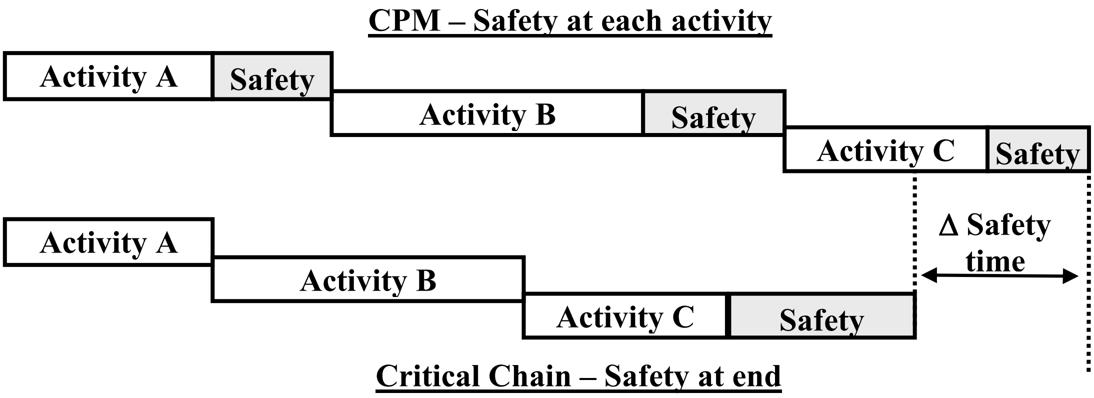

Figure 3. Comparison between CPM and Critical Chain regarding safety time

The first requirement is to ensure that preparations are made to start activities when they are passed over. One aspect of this is the creation of a resource buffer for activities on the critical path. The time of completion of ongoing activities is estimated, and the appropriate resources required for the subsequent activities are told to be available. The aim is that people know that when the time comes they must drop everything and work on the critical path. They are encouraged to start immediately, work only on the critical task and finish promptly. It is clear that is necessary to prevent multi-tasking is a crucially important aspect of project management that needs to be controlled (Rand, 2000).

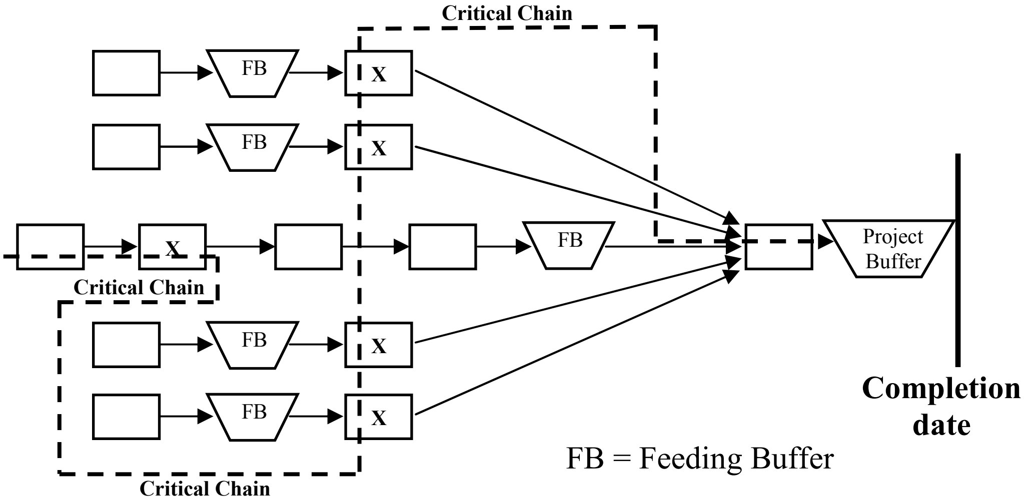

Figure 4. An example of critical chain (Goldratt, 1997)

The critical chain is defined as the longest chain of dependent steps: in other words, the constraint. To determine this, it is necessary to take into account any dependencies that might exist between activities because they require the same resource. If that is the case, they must be carried out sequentially rather than in parallel. This can be analyzed in the diagram shown in *Fig. 4*.

Last Planner System - LPS

The Last Planner System (LPS) was originally developed by Ballard and Howell in 1992. It is designed to increase reliability of planning as a mechanism to improve project performance.

Last Planner adds a production control component to the traditional project management system. Last Planner can be understood as a mechanism for transforming what SHOULD be done into what CAN be done, thus forming an inventory of ready work, from which Weekly Work Plans can be formed. Including assignments on Weekly Work Plans is a commitment by the Last Planners (foremen, squad bosses) to what they actually WILL do (Ballard, 2000).

The phase scheduling technique is used to develop a more detailed work plan that specifies the handoffs between the specialists involved in that phase. These handoffs then become goals to be achieved through Production Control. In other words, it is tried to achieve each handoff between specialists specified in the most highly detailed project schedule. They also recommend using pull techniques and team planning to develop schedules for each phase of work, from design through turnover. The phase schedules thus produced are based on targets and milestones from the APP and provide a basis for lookahead planning. The look-ahead has as its objectives to identify and eliminate constraints to achieve the milestones of the project, in a horizon that can be variable from four to eight weeks.

'Team planning involves representatives of all organizations that do work within the phase. Typically, team members write on sheets of paper brief descriptions of work they must perform in order to release work to others or work that must be completed by others to release work to them. They tape or stick those sheets on a wall in their expected sequence of performance. The first step of formalizing the planning and the phase schedule is to develop a logic network by moving and adjusting the sheets. The next step is to determine durations and see if there is any time left between the calculated start date and the possible start date' (Ballard & Howell, 2003).

The purpose of phase scheduling is to produce a plan for completing a phase of work that maximizes value generation and one that everyone involved understands and supports; to produce a plan from which schedule activities are drawn into the lookahead process to be exploded into operational detail and made ready for assignment in weekly work plans.

The weekly work planning process is built around promises. The agreed programme defines when tasks should be done and acts as a request to the supplier to do that task. The last planners only promise once they have clarified the conditions of satisfaction and if they are clear that the task can be done.

The LPS assumes that planning means selecting from what 'should' be done to complete a project and deciding for a given time frame what 'will' be done. Recognize that because of resource constraints, not all 'can' be done, and accordingly, if a subset of what 'should' be done 'can' be done, and a subset of what 'can' be done 'will' be done, then there is a high likelihood for what has been planned (will) be successfully completed ('did') (Ballard 2000).

5. PRODUCTION MANAGEMENT REQUIREMENTS VS. TOOLS

To analyse the methods of Production Management in construction we took as the base the requirements of the production system presented previously in section 3 (Koskela & Ballard, 2003). The Table 1 shows the findings of this analysis.

All methods of Production Management have their contribution, but as can be observed in Table 1 there is not one single method that completely satisfies all the requirements of the Production System. Each method has a weakness. For example, CPM does not identify the flow of resources through locations and it also uses a push-driven scheduling. On the other hand, LOB cares about location but this technique was designed to model simple repetitive production processes and, therefore, does not transplant readily into a complex and unpredictable construction environment. The Critical Chain method is recent, but it is still an evolution of the CPM, so it fails almost on the same points that CPM does. The most recent method presented was the Last Planner System. The LPS has two major focuses: short term planning and development of the social system on site. It has been applied with success in some construction companies, but it also has some gaps that still need to be improved. Some methods are also supported by software, but they are still not a total framework.

Table 1. Comparison between Production Management Requirements and Methods

REQUIREMENTS		CPM	LOB	Critical Chain	Last Planner
A	**Delivering the product**	**OK**	**OK**	**OK**	**OK**
	Minimizing waste	**NO** It is not involved with the process, just with scheduling.	**POORLY** Produce a task flow for even and continuous utilization of resources (workforce, equipments, materials, etc.)	**POORLY** Paying attention to the constraints avoids the waste of waiting time.	**PARTIALLY** Reduces making-do[1]; working backwards from a target completion date eliminates work that has customarily been done but doesn't add value.
	Maximizing value	**IMPLICIT**	**IMPLICIT**	**IMPLICIT**	**PARTIALLY** By reducing making-do kinds of waste, quality is increased
B	**Design of Production Management System**	**OK** Very useful to draft the first tasks sequence.	**OK** Flow concept.	**OK** Identify the tasks sequence and their constraints.	**PARTIALLY** Does not cover all project phases.
	Operation	**POORLY** It is difficult to keep it up to date. Software is needed.	**PARTIALLY** It is difficult to keep it up to date. Software is needed.	**POORLY** It is difficult to keep it up to date.	**OK** Because it works directly with the lowest level of production.
	Improvement	**NO**	**NO**	**NO**	**OK** There is a learning process involved.
C	**Peculiarities of Construction**	**OK** Can be used with any kind of project.	**PARTIALLY** Some authors argue that it is just useful for repetitive projects.	**PARTIALLY** Useful just for complex projects.	**PARTIALLY** In projects driven by equipment capacity, it is not very useful.
D	**Integration with all aspects of the Production System**	**NO** It is not linked with resources supply and people.	**NO** It is not linked with resources supply and people.	**NO** It is not linked with resources supply and people.	**PARTIALLY** It involves people synergy, but not resources.

6. CONCLUSIONS

The authors tried to demonstrate that there is a lot to be done on this area of Production Management. What is missing is a specific theory for construction. With a developed and tested theory, it would be much easier to develop a Production Management method that satisfies all the construction requirements. Furthermore, best practices would contribute to this development. As part of the first author's PhD programme,

[1] Making-do - Tasks are started without all their standard inputs (materials, machinery, tools, personnel, external conditions, instructions, etc.) (Koskela, 2004).

further research will be done in this field trying to develop such comprehensive production control concepts and principles, on which a usable method could be based.

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