LEAN CONSTRUCTION TRIAL ON A HIGHWAYS MAINTENANCE PROJECT

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ABSTRACT

In 2005, lean thinking was trialled to improve processes in the construction phase of a highways maintenance project. The trial was undertaken by a partnering framework; those involved were already working in a collaborative environment, and it was thought this would be conducive to introducing lean thinking.

The scheme involved resurfacing and deep patching of two four lane carriageways and the provision of concrete protection to eight bridge piers. During the construction phase, a buffered programme, four-week look-ahead programmes and weekly programme plans were used to: undertake constraints analysis; measure planned activities completed each week; and analyse root causes of delay. On completion, the Project Team were interviewed on the successes and failures of using lean thinking on the project.

Both problems and benefits were encountered in applying lean to the project. There were some issues with the way that lean was presented and certain improvements to the process were identified so that lean could be continued on other schemes undertaken within the framework, including: ensuring a better understanding of lean thinking and its application in a highways context; adopting some of the analyses as a formal process and measurement tool; and investigating principles of lean thinking outside programme management.

KEY WORDS

Highways maintenance, implementation, lean processes, partnering framework

INTRODUCTION

The Construction Management Framework (CMF) is an initiative established by the Highways Agency, the executive agency responsible for managing and maintaining the motorways and trunk roads in England, in two of its regional areas to deliver highways renewals and improvements schemes (Wolbers, 2005). Construction management was employed as the procurement route to allow direct contractual relationships to exist between suppliers and the client, with a partnering relationship existing between specialist trade contractors, the construction manager and designers, to achieve best value in the work associated with the framework (Bryde and Brown, 2004). A Construction Management Framework Community was established to facilitate this partnering ethos,

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with various groups set up to guide the framework in the areas of processes, measurement and culture, which encompass the sub-groups of innovation and communication (Construction Management Manual, 2002). In 2005, it was decided that recommendations for the use of lean thinking from the Egan report "Rethinking Construction" (Egan, 1998) could be explored on a Construction Management Framework project as part of the vision to deliver industry-leading performance. A highways renewal project was selected to pilot lean thinking during the construction phase, and an external consultant was employed to assist with the process. This paper describes the lean thinking process that was used on the pilot scheme and considers the effectiveness of the process based on discussions with the Project Team.

LEAN CONSTRUCTION IN PRACTICE

Lean thinking has recently been introduced as a way to improve processes and adding value in the construction industry. Evidence of the use of lean thinking has shown that there are benefits to be made from applying lean principles to construction, although tools for implementing lean concepts are not well established (there are many contributors to literature of lean construction, among them: Howell [1999], Ballard [1998, 2000], Ballard and Howell [2003], Koskela [2000], Bertelsen [2002], and Bertelsen and Koskela [2004]).

The Last Planner system (Ballard, 1999) is a tool that has been developed which concentrates on the planning function of construction, using a sliding window (Lookahead Plan) to plan what can be done when constraints are removed. An important function is the Percent Planned Complete (PPC) which monitors the Lookahead Plan and requires reasons for delays, which are analysed in terms of root causes. Elements of the Last Planner system were adopted on the Construction Management Framework lean thinking pilot scheme.

It is foreseen that some of the problems identified with implementing lean construction by Alarcon and Diethelm (2001) in their study of seven Chilean construction companies, could be overcome through utilising the community arrangement of CM. Ballard (1998) identified that product and process design can be standardised for standard products but standardisation of non-standard products must be done at the planning level. This is often prevented by fragmentation between interfacing parties in the construction industry; however process mapping and trust are used within CM to achieve a cohesive and unified community, which, in theory, facilitates improving systems, rather than simply defending individual interests.

THE PILOT SCHEME

The work on the pilot scheme primarily comprised: three miles of carriageway renewal with deep patching up to an additional 100mm to full-lane width in designated areas of carriageway; and structural strengthening to eight existing piers at three bridges. The Project Team included the Highways Agency as the client, a construction manager, and five specialist contractors: surfacing, general civil, traffic management, electrical and safety fencing, and their supply chain.

The work was planned to start on site of 10th October 2005, with all traffic management (TM) to be removed by 22nd December 2005, and completion of non-TM works on 9th January 2006. An item for inclement weather was included, so that the finish date for the programme was 16th January 2006. This programme was assessed in

terms of "leanness", with the duration of each activity reduced by approximately 20%. The lean thinking programme showed all TM removed by 14th December 2005, and completion of non-TM works on 19th December 2005. A buffer protecting completion of the works was included as an item to the end of the works. The work commenced on site on 10th October 2005 and all TM was removed by 18th December 2005 with all works completed by this date.

LEAN THINKING PROCESS

The lean process adopted on the pilot scheme is discussed in terms of lean programming, the analyses that were carried out, and the outputs from the analyses.

PROGRAMMING

In the construction documents, a Task Order programme was produced by the Project Team for the works. This programme was used to create a "lean" programme, by reducing the duration of each activity by 20 per cent to account for risk built into activities. The portion of time removed from each activity was then added together to form a buffer that was placed at the end of the programme to protect completion of the works.

ANALYSES

Analyses comprised three activities: constraints analysis, delay analysis and buffer analysis, as discussed below.

Constraints Analysis

Constraints analysis involved using a chart in an Excel spreadsheet to identify the preparation that was required to "make ready" activities planned to start in the next four weeks. The preparation activities were established at the beginning of the project and included items such as drawings and design, method statement, temporary works and materials. The analysis was undertaken as a team exercise during planning meetings using a chart prepared prior to the meeting which listed all activities in the next four weeks. A cross was placed under corresponding items that prevented an activity from starting, and a person was assigned the responsibility of ensuring that the constraint was removed by a due date. An activity was not deemed ready to start until there were no crosses against any of the preparation activities, signalling that all constraints had been removed.

Delay Analysis

Prior to the weekly meeting, a two-week plan was prepared based on the programme which was updated weekly. During the meeting, the two-week plan was tabled and, as a Team exercise, revised based on input from the appropriate specialists. The two-week plan was used weekly in the delay analysis. Information was collected by a representative on site at the end of each week of the activities that had been completed by the dates shown on the two-week plan. If the activity had not been completed on time, a reason for the delay was required, from a prescriptive list defined prior to the start of works on site.

Buffer Analysis

Software was used to analyse penetration into the buffer as the project progressed. Information was collected on site of activities completed in the week, with each specialist identifying how many days remained on activities not completed. The information was fed into the software which calculated how much of the buffer had been used, based on the actual duration of critical activities compared to the "lean" duration, with any overrun taken from the buffer. The penetration into the buffer was represented as a percentage of the entire buffer duration. Protection to the buffer was also calculated. The protection ratio was a calculation of the buffer that should be remaining according to the remaining duration of the project, and the buffer that was actually remaining.

OUTPUTS

A weekly plan attainment chart showing the percentage of activities completed each week against the weekly plan was produced as a bar chart (see Figure 1). Pie charts showing causes of delay was also developed; one pie chart was adapted to include a category for non-completion of the preceding activity (see Figure 2a). A second pie chart was formulated to carry the initial cause of delay onto following activities that were also delayed (see Figure 2b). The first pie chart was used to illustrate the cause of initial delays, with delays caused to following activities attributed to a category titled "preceding activity not completed". The second chart shows the effect of different causes of delay on following activities, so that delays to following activities were attributed to the initial cause of delay.

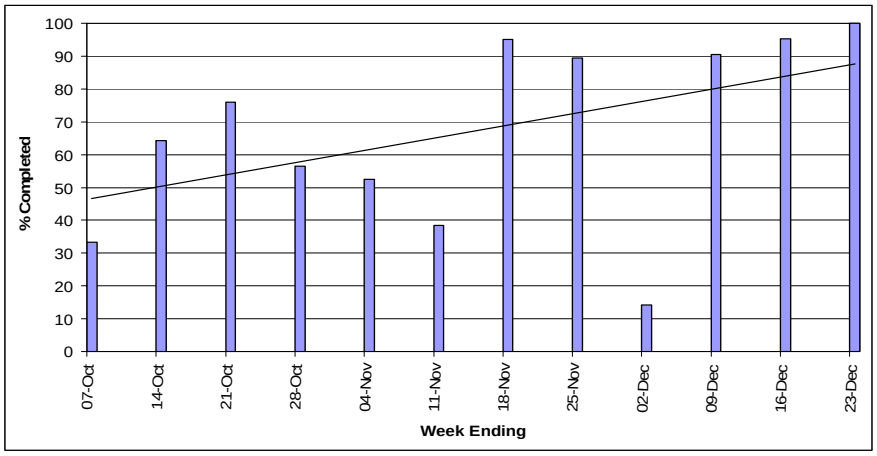

Figure 1: Weekly plan attainment chart

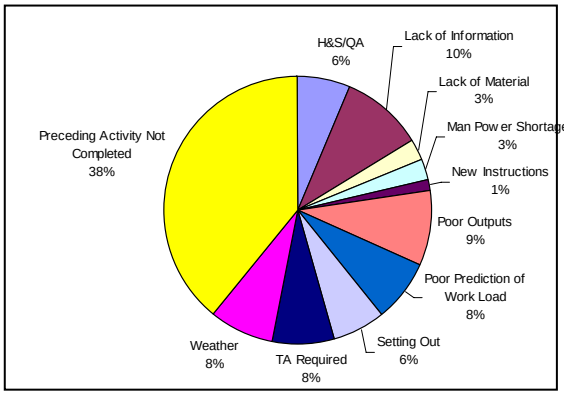

Figure 2a: Delay Analysis Chart including category for preceding activity not completed

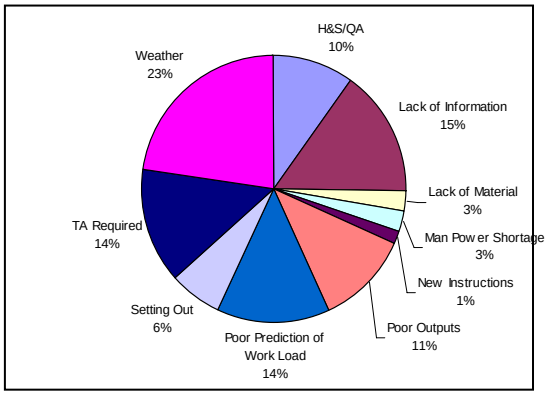

Figure 2b: Delay Analysis Chart without category for preceding activity not completed

A buffer chart was produced from the buffer analysis information using a line graph (see Figure 3). The chart area was divided into red, yellow and green: the red signalling danger to the project completion date; yellow signalling the programme needed to be monitored to ensure the completion date was safe; and green being the completion date was safe. A blue line was shown on the chart to signal full use of the allotted buffer for project progress. The actual percentage of buffer used was plotted against this weekly, with the red zone beginning around 10-15 per cent below the blue line.

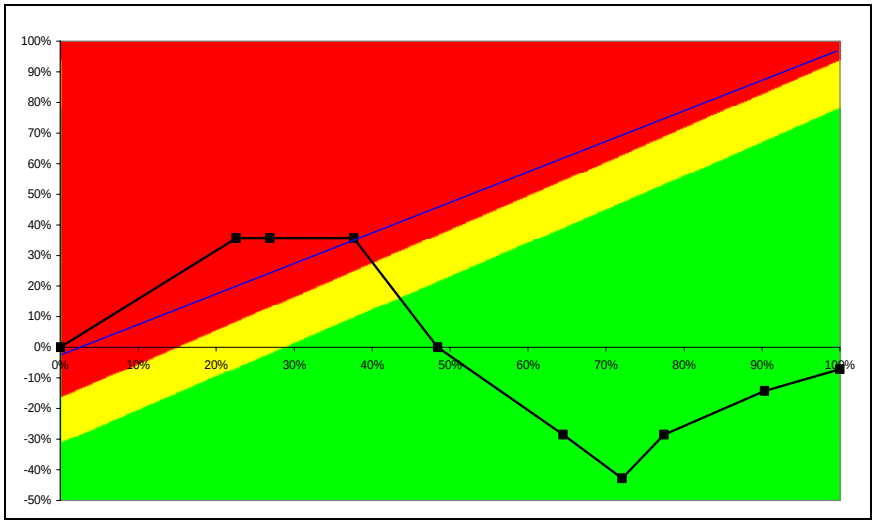

Figure 3: Buffer chart

REVIEW OF THE LEAN THINKING PROCESS

PROGRAMMING

There were some problems encountered with the "lean" programme that was produced from the original Task Order programme. The original programme had included "dummy" links which allowed works to be arranged around the critical surfacing activities. In making a "lean" programme, these links were taken out moving non-critical activities onto the critical path. When these were not completed by the revised "lean" date

in the first few weeks of the works on site, the project was shown as running behind schedule leading to outputs that showed the completion date was in danger of not being met when this was not actually the case.

The duration of every activity was reduced by 20 per cent to account for risk built into activities; however a draft procedure has been developed by the CM Community for the development and control of programmes. This procedure considers identifying a time risk allowance for each individual activity, thus creating a more accurate and "leaner" scenario.

Creating a "lean" programme highlighted a problem with attempting to shorten activity durations during night time TM closures in that an activity cannot commence within a closure if it cannot be completed to the extent that it would be safe to lift the closure. Therefore it would be futile to expedite a preceding activity if no following activity can commence within the same closure.

ANALYSES

Constraints Analysis

Preparing the constraints analysis chart and carrying out the analysis were both time-consuming activities, with the chart updated each week according to the revised master buffered programme and many repetitive items to discuss in the meeting. However, most of the Team identified it as a valuable exercise that disciplined the Team to focus on planning ahead, and gave structure to the planning meetings.

DELAY ANALYSIS

Developing the two-week plan as a Team exercise was identified as a valuable exercise by some of the Team, because it committed the Team to a plan, producing targets which could then be communicated to the workforce. However, the two-week plan produced in line with the weekly updated buffered programme rarely represented what was actually happening on site, according to the Team's planned activities. This became particularly noticeable as awareness was raised that performance against the weekly plan was being measured, and the Team began to make more achievable promises. The two-week plan from the master programme was compared with the Team's planned activities, 10 weeks into the 14 week programme. The comparison showed obvious differences between the two programmes. Of the 55 activities, only 2 (3.6 per cent) which were shown on the master programme were planned to start on the same day on the two-weekly plan. Most activities were planned in the weekly meeting to start on site a week later than shown on the updated master programme, and other activities starting on site were not shown to start on the master programme within those two weeks at all. While this did not present a problem when there was no threat to the completion date, straying so far from the master programme may have a more detrimental effect if there was a greater risk that the completion date would not be met.

BUFFER ANALYSIS

The buffer analysis in the first few weeks of the project showed that buffer penetration was greater than it should have been, thus endangering the completion date, because non-critical activities had been placed on the critical path in converting the original programme to a lean programme. Once the programme was modified to correctly reflect

the criticality of the works, buffer penetration was shown as below zero per cent. However, this was not entirely accurate either, because in the period showing zero per cent buffer penetration, problems were encountered on site which delayed the programme. Additional works that were required and problems with ground conditions delayed works by one week, however at this stage the buffer penetration was minus 29 per cent. The Team, however, were aware that the programme had slipped, and began to investigate possibility of gaining back time as a matter of course as the Team were focussed on the removal of TM before the Christmas period. The negative use of the buffer was shown through to the end of the project because it was based on the end date of the project including completion of non-TM works, whereas it would have been a better representation of the focus of the site team if the buffer protected completion of works reliant on TM, and the removal of TM.

OUTPUTS

The output from the process highlighted several points, including:

- attainment against the weekly plan averaged 67.1 per cent for the scheme, with a positive trend as the scheme progressed;
- the majority of initial delays occurred because preceding activities were not completed, with lack of information and poor outputs being the next two categories causing the most delays; the causes of delay which had the worst effect on the completion of activities was weather, followed by lack of information, the requirement for technical approvals and poor prediction of workload; and
- the project was completed without using any buffer (leading to some concern that the initial programming of the job was inaccurate).

The weekly progress chart was an indication of how well the team members were meeting their commitments, and while it is impossible to tell from the analysis if critical tasks were completed on time, it provided an incentive for the team to meet their targets. It was possible to correlate the chart against events on site, for example where the percentage of activities completed was lowest in the week ending 2nd December, weather had been the mitigating factor.

It was considered by some Team members that the output showing causes of delay were of more interest for comparison across schemes, and not as relevant on a scheme basis, perhaps because of the short duration of the project. There was very little understanding among the Project Team of protection ratio to the buffer, and it was generally agreed that the graphs were not well explained or presented, and held little meaning for the project.

Generally, the contribution of lean to the success of the project was difficult to establish. There were mixed responses from the Project Team, with some agreement that while the same outcome may have been achieved without using lean, there was less "firefighting" and fewer problems in the day-to-day running of the project. Lean could be measured either using the outputs from the process to formulate a key performance indicator (KPI) for weekly progress either against the master programme or the weekly planning programme, or to establish a lean conformance measure by setting out the objectives of lean on CM schemes and measuring performance against those objectives.

LEADERSHIP OF THE LEAN TRIAL

The success of the lean trial was closely linked by the Project Team to leadership of the lean process, and should be reviewed in line with the comments made by the Team. Lean construction was introduced to the Project Team through either a one full-day or one half-day seminar, depending on availability of the Team members. Lean thinking was initiated at design Early Contractor Involvement (ECI) stage, when the programme was being developed which allowed the addition of a buffer to the construction programme produced by the team. Once construction began, a segment of the weekly planning meetings was allocated to lean thinking, in which constraints analysis, delay analysis, buffer analysis and the updated buffer programme were discussed.

The general opinion of the Project Team was that there was not a good understanding by the team members of lean. Not all Team members attended the briefing given at the start of the project, and of those that did, there was still some misunderstanding of what was trying to be achieved. The delivery of the training was described as poor, and more could have been done through leadership of the lean process to overcome the gap in understanding, or to understand the nature of the works and the effects on the programme. There were problems with failing to maintain the logic of the programme when the buffer was applied, which lead to some of the team dismissing the validity of the outputs of the process, in particular the buffer penetration and buffer protection charts. Although the team appreciated the value of the constraints analysis and weekly planning, and to some extent, the delay analysis, it was felt that these were done in the past anyway, without the discipline and formalisation applied through the lean process.

In addition, the lean process that was adopted addressed the project management function of lean, but overlooked other principles, in particular the concepts of value and waste. To be lean, work needs to be structured for value generation, and anything that is not value, i.e. waste, should be removed. Therefore, value and waste must be identified and controlled, as explained by Ballard and Howell (2003).

FUTURE PROJECTS

The contract for the Construction Management Framework is for seven years, ending in July 2009; thus there is the opportunity to learn and continuously improve from one scheme to the next. The areas that were seen as successful during the lean pilot scheme can be carried on as tools to be used on future projects, while overcoming the problems must be a focus if commitment to being lean is to be achieved. Programming is currently carried out as a team exercise; however, honest identification of time risk added to activities will enable truly lean programmes to be produced. While trust is an issue here, contemporaneous data collection on site will provide an accurate basis for predicting activity durations.

Presentation of output can be aligned to the audience it is aimed at. Diagrammatic representation of the use of buffer is appropriate for managers and those not closely involved in the construction to gain an overall view of progress, while site staff have an in-depth understanding of progress and gain more from measurement of their performance against weekly plans. Deciding what works best as a team will help to create commitment and ownership to the process, and may lead to improvements in the way outputs are presented.

Lean was presented to the members participating in the pilot scheme as tools that can be used to manage the construction programme. While there was resistance to even this

simple explanation of lean, the boundaries of lean must be broadened if the Construction Management Community is to gain the full benefits. Lean is a culture change, and introducing lean needs to be approached as introducing change. This requires commitment from high level management that filters down throughout the organisation, using change agents to lead the change, challenging the current way of working to enable people to identify the need for change and choosing the right levels of communication to gain acceptance of the change (Johnson et al, 2005).

Engaging the workforce in the change process will naturally lead to encouraging worker participation in creating a lean approach to the schemes that they work on. This requires all members of a scheme, from management to operatives, to be aware of their role and importance in adding value, first ensuring that there is a shared definition of value; a definition that aligns with the client's objectives. Thus participation is required at the outset of schemes from all levels of the workforce, and all members of the scheme, in defining value and defining roles and responsibilities. This should be followed with active encouragement of ideas from the workforce for adding value and eliminating waste, through structured workshops, visual indicators and continual feedback.

CONCLUSIONS

The Lean Thinking Process used on the highways renewals scheme has been discussed in terms of programming, analysis and review, including problems in producing and maintaining a buffered programme, benefits of the weekly constraints, planning and delay analysis and usefulness of the various output from the process. Certain improvements to the process could be made if lean is to be continued onto other schemes in CM, including adopting those tools that worked well as a formal process, creating a better understanding and "buy-in" to lean from the outset, identifying time risk allowance for each individual activity, and investigating principles of lean outside programme management.

Introducing the lean process to a highways scheme was a challenge. Previous examples came from the building industry, and the applicability to highways was difficult for some of the Project Team to see without tried and tested specific examples. In much the same way some argue that a production factory is different to a building site, so too it was seen that a building site is different to the highways construction environment. The constraints are markedly different: a priority for those working in highway is to ensure works create minimal disruption to the travelling public. Works take place where they can; not so much due to working space allowed by other contractors, but by working space allowed by the traffic management designed to cause minimum disruption. Understanding these differences, and showing how lean tools and techniques can be adapted to give full potential in a highways context, is fundamental to creating support for lean in this environment.

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