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THE DEVELOPMENT AND USE OF LAST PLANNER® SYSTEM (LPS) GUIDANCE

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ABSTRACT

This paper addresses the development and use of last planner system (LPS) implementation guidance. Lean construction (LC) as operationalised by tools including the LPS has been deployed over 25 years with documented successful outcomes. Yet, the literature also reveals widespread implementation failures, in part due to a guidance shortfall. To address this issue, guidance principles were developed, informed by longitudinal action research (AR) undertaken over 18 months investigating LPS usage on 7 sequential projects on the ongoing refurbishment of a liquified natural gas (LNG) plant in North West Australia.

AR, the main research method used, combined continuous experimentation with analysis using a variety of data and evidence sources. By examining the process and outcomes of the action, explanations and further ideas are forthcoming, setting the platform for new action. The paper describes further longitudinal LPS implementation aided by the developed guidance on a £1.5 billion UK infrastructure project.

The research contributes to knowledge with ongoing LPS guidance development, through testing and refinement with AR cycles. Further guidance into the use and melding of off-site manufacture and lean construction practice is also being developed and deployed. The limitations are that only LNG refurbishment and infrastructure projects have been researched to date.

KEYWORDS

Lean construction (LC), Last planner system (LPS), lean construction guidance, Action Research (AR)

INTRODUCTION

Chronically low workflow reliability with attendant work flow variability in construction projects, was identified in 1992, as a main factor causing construction underperformance by Glenn Ballard and Greg Howell (Kalsaas, et al. 2015) This discovery spurred the development of LC, with a suite of tools including the LPS, developed to reduce workflow

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variability. Ballard et al. (2016) in describing the history and evolution of the LPS says that its first aim was to improve workflow reliability, achieved by collaborative meetings between first line supervisors, producing weekly co-ordinated work plans. These decision makers involved in planning and delivering the work were termed Last Planners (LPs). They must fully understand their own work and have the authority to make decisions, with assistance by those who can provide information required on aspects of safety, quality, logistics and master programming. Planning is undertaken in reverse order, driven by the prerequisites of each activity, with outputs used to develop detailed schedules aligned with master schedule milestones (Ballard et al. 2016). Traditional planners are called First Planners.

The master schedule normally using critical path method (CPM) software, sets cost and schedule targets aligned with project scope, whilst monitoring progress toward those targets. The task of LPS production planning is to steer projects towards CPM derived targets. For efficacy both must operate in harmony. Huber and Reiser (2003) note that commonality can be achieved between CPM and a collaborative planning system implementation and Olivieri et al. (2016) proposed a model to systematise the integration of LBMS (Location based management system), LPS and CPM. Yet, obtaining the required CPM/LPS synergy is challenging, Issues include ineffectiveness in dealing with multiple constraints such as deadline and resource limits (Hegazy and Menesi 2010), not allowing for the interruption of activities (Shi and Deng 2000), and reported misuse of the software to produce illogical impractical schedules (Korman and Daniels 2003). Furthermore, delinking is used to make the schedules “work”, with reporting not reflecting “reality” and complex scheduling produced that management and supervisory staff struggle to interpret (Hackett 2017).

Notwithstanding issues described, LPS implementation itself proves a challenging process, with successful outcome realisation problematic due to several factors. These include a lack of appropriate training, a lack of senior management support, an inability to motivate people, a lack of honesty and trust between participants and a failure to select and train the right people (Cano et al. 2015). Furthermore, research reveals a paucity of implementation guidance. Howell et al. (2002) outlines nine implementation steps, Mossman (2012) provides some general advice on LPS implementation, and there is some discussion on guidance provision (Fernandes et al. 2016, Mejía et al. 2016). Yet, in the main there is little evidence of specific guidance for LPS implementation with a lack of implementation know-how still one of the main barriers to lean construction implementation (Zanotti et al. 2017). The research was undertaken in part to address this issue, whilst addressing the challenge of harmonising LPS and CPM usage.

There is also limited research on establishing a relationship between PPC metrics and performance. Ballard and Howell (1994) demonstrated improved productivity performance of 30% with crews achieving a PPC above 50%. Liu and Ballard (2008) in statistical analysis of a pipe installation project established positive correlation between rising PPC metrics and productivity levels. Here the contractor achieved costs improvements of 24%, aligned with consistently high PPC levels, Yet, research on correlation is limited, a gap addressed in this research.

The paper describes the initial research and its outcomes, including guidance developed. Subsequently, the guidance was used to assist LC implementation on a UK infrastructure project. The implementation is described using several case studies to demonstrate positive outcomes, setbacks and how these setbacks are used to evolve practice particularly in forming synergy between lean construction and lean production practice.

RESEARCH METHOD

Initial research was undertaken on the ongoing refurbishment of an integrated liquefied natural gas (LNG) plant, the 200 ha Karratha Gas Plant (KGP) in the Pilbara region of western Australia. Deterioration over time of the protective cladding, insulation and paint systems has resulted in local external corrosion of pipe-work and vessels, requiring corrective maintenance. The refurbishment work is being implemented over a five to ten-year period, extends the operating life of the plant. Work is carried out on a working plant, with projects undertaken online (on live plant) and offline (on isolated sections of plant). The short and intense nature of the projects enabled investigation of LC implementation with lean tools used including the LPS on 7 projects undertaken sequentially over an 18-month primary research period. LPS implementation included the use of pull planning, weekly work planning (WWP) and daily huddles (DH).

AR, the research method used, integrates "learning by doing" where learning is aided by reflection (Coughlan and Bannick 2012). Learning is used to bring about change, by collaborating with those who do the work and who will eventually embed worthwhile change. AR combines continuous experimentation with analysis using several forms of data and evidence. By examining the process and outcomes of the action, a platform is set for continual improvement (Burns 2007), where organisational issues and the people interacting in these issues are part of the research process (Coghlan and Brannick 2012). The use of this method had the merit of philosophy alignment between AR and lean construction, where lean is characterised as enabling people to learn and learn how to learn. (Hackett 2017).

RESEARCH OUTCOMES

Analysis of 20 semi-structured interviews on CPM usage was undertaken to assist in its melding with the LPS. A further research outcome was the development of the guidance principles listed and described below, with a principle defined as a proposition that is a guide for behaviour or evaluation.

Guidance Principles

1. Obtain real buy in and support from executive management including clients
2. Identify and engage formal leaders especially senior management
3. Identify and engage informal leaders
4. Identify and engage change agents
5. Use early development of a high-level strategy and a robust logical milestone map
6. Use of master schedule milestones to inform the LPS pull planning process
7. Use a disciplined approach
8. Use of boundary objects
9. Use LPS meetings to assist continuous improvement and innovative practice

10. Use pre-existing lean or lean type knowledge and existing initiatives
11. Standardise good practice and continuous improvement.

The principles are described as follows.

1. *Obtain real buy in and support from executive management including clients*. This is referred to as gaining political cover, essential prior to any embedment process. Support may be demonstrated by mandated use of lean construction identified in contract and procurement documentation.
2. *Identify and engage formal leaders especially senior management.* The engagement of formal leaders especially senior management is pivotal to successful implementation. Leaders with prior positive experience and knowledge of a lean approach tend to provide higher levels of continuous support. Continuous support is demonstrated by consistent attendance at the LPS meetings, mainly in a watching brief, but providing guidance as necessary allowing decision makers to take control, whilst offering direction as dictated by the meeting flow.
3. *Identify and engage informal leaders.* Informal leaders exert influence over the team, come from the team and are chosen by the team (Pescosolido 2001), are willing to stand up and act to influence the behaviour of teammates through means other than formal authority (Ross 2014). A shared team vision encourages the emergence of informal leaders who play a key role in developing group efficacy, enabling team mates to achieve at higher levels than normal (Zhang et al. 2012). AR demonstrates that they tend to be supervisors, site engineers and project engineers, identified at forums such as H&S pre-start meetings.
4. *Identify and engage change agents.* Change agents are defined as those who assist in organisation transformation and continuous improvement. Change agents tend to be formal leaders previously involved in successful implementation of LC or LC type approaches on the current or other projects.
5. *Use early development of a high-level strategy and a robust logical milestone map.* Strategy development involves a reasoned short description on work sequence informing the development of a robust master programme, whose milestones direct production planning.

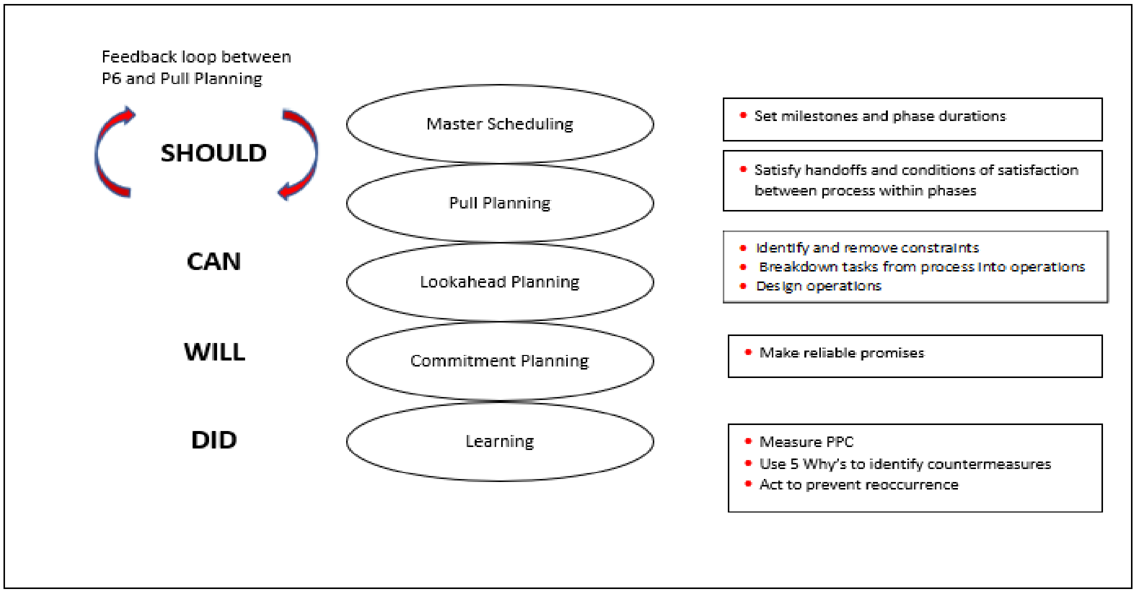

Figure 1: Current process benchmark for the last planner system (amended), (Ballard and Tommelein 2016)

6. *Use of master schedule milestones to inform the LPS pull planning process.* The meetings use the process benchmark (figure 1), which directs the implementation of LPS production planning as informed by master scheduling project milestones,
7. *Use a disciplined approach.* Timings for the DH, WWP and pull planning meetings must be agreed by common consent. All meetings must start at the agreed times, following a set procedure with decision makers fully prepared. Particularly avoid overburdening with an excess of new and inexperienced LPs with coaching and mentoring provided in advance. Commitments can only be made by the LPs.
8. *Use of Boundary Objects.* Boundaries present barriers to knowledge transfer. Boundary objects are defined by their capacity to serve as bridges between intersecting social and cultural worlds. Carlile (2002, 2004) identified three boundaries; syntactic, semantic and pragmatic. Syntactic boundaries are created by differences across groups in terms of the use of different language, grammar and symbols. Semantic boundaries are caused by differences in accepted interpretations and meanings, where knowledge needs to be translated rather than just transferred. Examples include the different interpretation of risk between those from an engineering and legal backgrounds. Pragmatic boundaries occur when groups involved in collaborative practice have differing or conflicting interests, where solution agreement is blocked by self-interest. There are a range of boundary objects, including BIM models, forms, sketches and drawings, mock-ups and narratives. In the current implementation a primary boundary object is the magnet used in the LPS process.
9. *Use LPS meetings to assist continuous improvement and innovative practice.* The LPS meetings are an opportunity for decision makers to interact and pool experience and

knowledge to aid constraint identification and removal as well as innovative practice development and opportunity realisation.

10. *Use pre-existing lean or lean type knowledge and existing initiatives.* Leaders/informal leaders with positive implementation experience or who intuitively use lean approaches can become implementation enablers. People include superintendents/works managers, general foremen, supervisors and managers. People identified are some of the most supportive in the implementation process, leading and mentoring the implementation. One of the first and most important implementation phases is the identification and engagement of such people.
11. *Standardise good practice and continuous improvement including evolution of the tools.*

A further aspect investigated was the correlation between PPC levels and performance.

ONGOING LPS IMPLEMENTATION

OUTCOMES

The LPS is being implemented and further refined using AR principles on a 34-kilometre UK infrastructure project over the last 2 years, where the use of LC is mandated and supported by the client Highways England. Differing outcomes from the ongoing usage are investigated, particularly as it affects performance and continuous improvement. Whilst literature and the ongoing research demonstrated considerable issues with the use and worth CPM, it is now integral in traditional construction and must be engaged with. Therefore, the research has investigated the amalgamation of the CPM and the LPS. To do this, the P6, which sets project direction is constantly refreshed and updated by pull planning meetings, where a bridge is established between the two approaches of traditional and lean construction (figure 1). Further research was undertaken in aligning lean construction and lean production approaches.

Case Study 1:

The earliest LPS usage on the current project was on the construction of an interchange and associated works, aided by the guidance principles. There was evidence of support and engagement by formal and informal leaders, with pre-existing lean knowledge demonstrated by some team members. This knowledge was used in the development of the WWP board (figure 2), reporting on the previous week, planning what WILL be completed in the upcoming week and CAN be completed in the following 4 weeks. A disciplined approach was employed in the implementation of the LPS meetings, with timings and procedure set and adhered to by mutual agreement. There was also evidence of autonomous development of practice. This included the use of the WWP for early identification of procurement requirements (figure 2). Furthermore, the board was used to level resources. Resource levelling i.e. balancing labour and plant availability represents an ongoing challenge in the construction industry. This challenge was addressed in autonomous change introduced by a contractor decision maker where a second pass was instituted after the initial weekly planning, with some re- timing of non-critical activities as required to level resources. This resulted in more effective use of labour and plant resources, smoothing work flow.

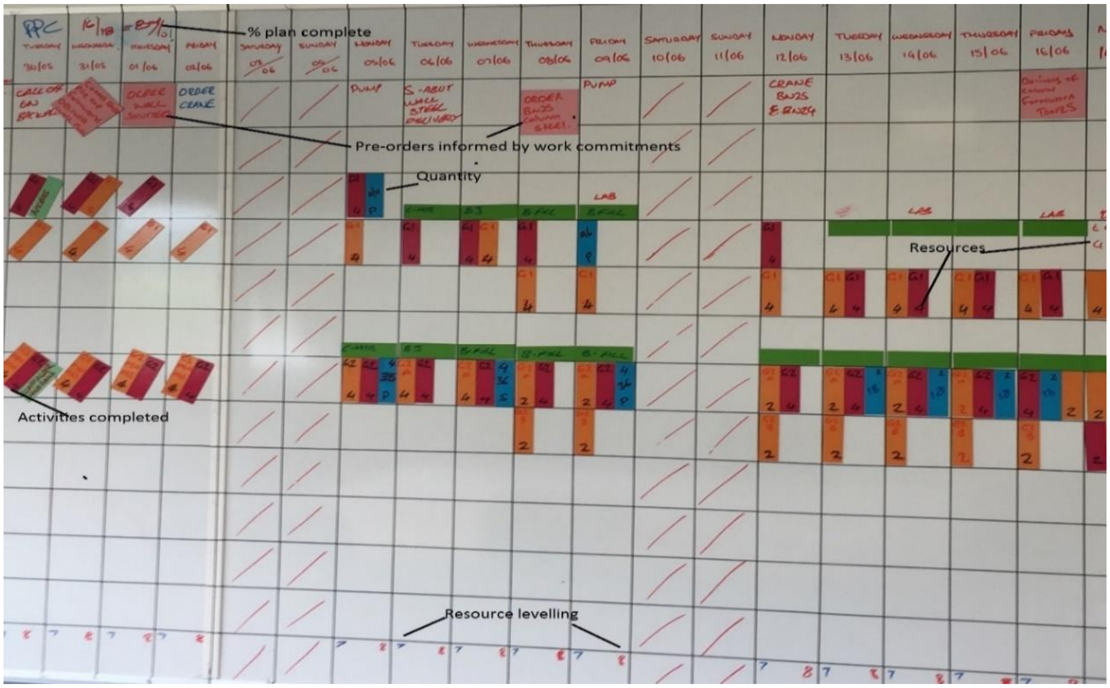

Figure 2: Evolution of practice

Furthermore, the LPs used the WWP to transfer knowledge and information, assisting continuous improvement, immediately deployed in production. Solutions and opportunities implemented included the following: pre-decking a section of the bridge under construction to directly load reinforcing off delivery wagons, use of couplers to improve workflow and productivity. However, whilst constraints were identified there was some resistance to constraint identification and ownership of constraint removal. This is an important element of the LPS philosophy, differentiating it from traditional construction. This was recognised as a failing with more disciplined constraint analysis used on subsequent implementation.

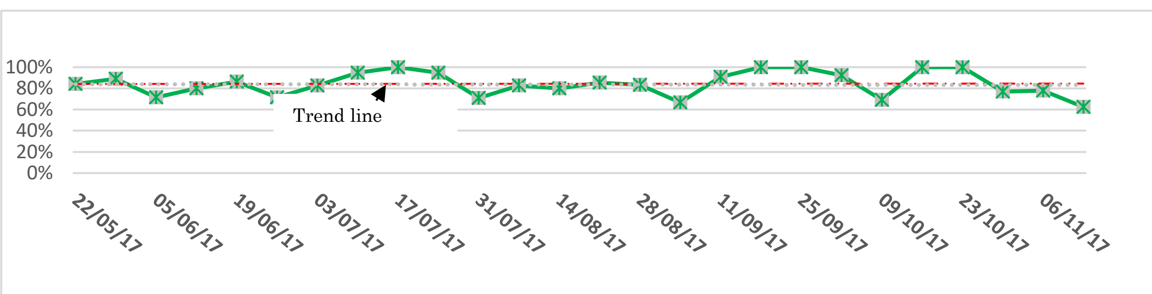

Figure 3: PPC data

Performance improvement identified included the development and use of innovative practice as described. Furthermore, high and steady PPC metrics (figure 3) correlated to a 25%, schedule compression with a 6 weeks compression in 7 months achieved. This aligned with the previous research outcomes (Hackett, 2017). Lessons learned including confirmation of LP ability to develop innovative practice and the recognition of the need for more disciplined constraint analysis. These lessons informed ongoing implementation.

Case Study # 2

In this instance, the LPS was implemented on a section including the construction of extensive bridge and associated works, where issues with the lean production process were revealed. Here the term lean production is used to describe off site manufacturing and prefabrication of components. In the enabling construction phase, including earthworks, piling, abutment and pier construction high PPCs trends were recorded. These aligned with performance improvements including a 20% schedule compression achieved over a 6-month period. Conversely, with the commencement of structural steel erection, PPC metrics were lower and more variable, trending at 55% with a corresponding schedule underperformance. PPC levels and performance outcomes improved after 5 months trending at 75% but dipped again with precast unit installation commencement. These findings run counter to preconceptions that offsite manufacture implementation positively impacts the construction process. Research to determine reasons using informal conversations, lessons learned workshops, observation and trend analysis to collate the following reasons for performance achieved revealed the following:

- A lack of pre-planning and interface with supply chain and sub- contractors.
- A limited use of BIM as a visualisation tool.
- Failure to adhere to pre-planning undertaken – particularly sequencing
- Breakdown in logistics control- deliveries out of synchronisation
- Traditional construction mind-set predominant
- Use of batch and queue rather than just in time (JIT) logistics
- High amounts of defects with dependence on expediting at the end of process.

These lessons learned were applied on other work fronts, one described below.

Case Study #3

This section of critical scope consists of some of the more complex work on the scheme, involving, new motorway interchange and structures construction, reconstruction and demolition on live infrastructure, whilst dealing with numerous complex constraints including major utility diversions, archaeological excavations, interfacing with local business' and residents whilst maintaining traffic flow on a major arterial traffic route.

The LPS had been employed on this section with implementation supported and developed by leadership with previous lean construction experience and informed by current embedment. Again, implementation was directed by the process map (figure 1) but with greater focus on synergy development between the P6 programme and LPS pull planning. Milestones developed were used to populate WWP meetings (figure 4). The embedment was relatively quick, aided by strict adherence to the guidance principles. This was enabled by the formal and informal leadership. Dave et al. 2015 notes a widespread lack of synchronisation and integration between LPS and CPM, with a need for a more comprehensive approach to unification. In response to these and similar criticisms, and after some early setbacks a tight interrelationship was established (figure 1), with high level milestone maps continually updated in fortnightly pull planning meetings. Here the

 Reasons for non completion

constraints likely to impede workflow are identified for removal with ownership designated. In addition, the P6 master programmes was updated monthly, using an integrated pull planning meeting attended by planners, relevant decision makers, including principle contractor and subcontractor senior management.

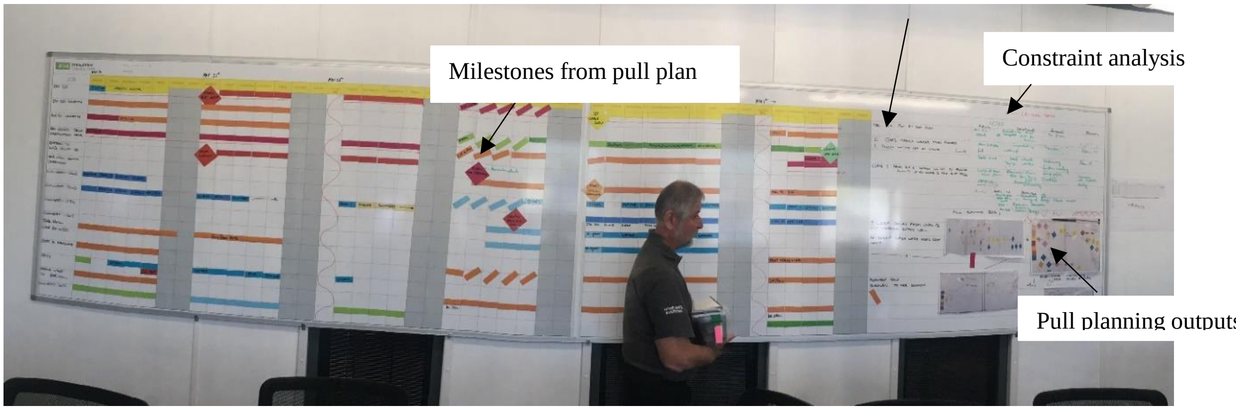

Figure 4: WWP using P6/pull planning milestones.

Figure 5: Pull planning meeting

Off-line manufacturing and fabrication were employed, primarily on the construction of 2 bridges with the decks manufactured off line and transported into place using self-propelled mobile transport (SPMT). Here, previous knowledge gained, and learning outcomes above guided the LPS implementation. This process involved the use of the LPS (figure 1), commencing 9 months prior to the proposed lift dates. Ongoing pull planning engaged decision makers including main contractor, sub-contractor and supply chain using BIM as a visualisation tool (figure 5). Furthermore, animation was employed to guide and inform the work flow (https://bit.ly/2QrS9cF). Again, pull planning meetings were integral to continuous collaborative development of tightly interrelated CPM schedules and LPS production planning.

A JIT approach was employed for deliveries of steel and reinforced concrete components. There was conscious shift from a push approach to a lean production one with a focus on maintaining previously developed sequencing with defects free components arriving at work fronts. This approach was assisted by rigorous collaborative quality control aided by designated QA personnel verifying component quality prior to delivery.

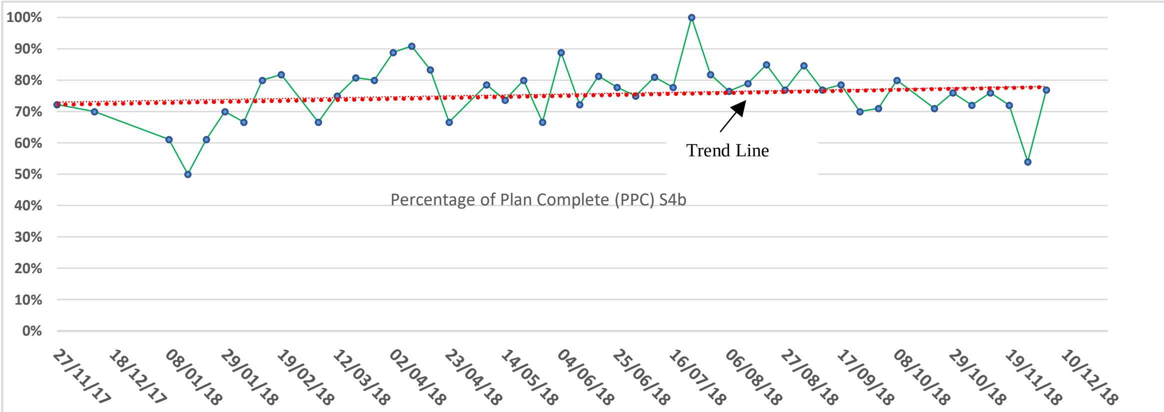

Figure 6: PPC trends

This implementation is one of the more robust, with early consistently high PPC metrics achieved (figure 6), correlating to enhanced schedule performance and continuous improvement. The SPMT lift, a critical path activity achieved schedule compression of 4 weeks, equating to a 25% performance improvement, with a world first of a dual SPMT deck lift over one weekend closure (https://binged.it/2TBDTQM).

CONCLUSIONS AND DISCUSSION:

The paper described ongoing LPS implementation and development using a scientific approach in the form of AR. Here, implementation is cyclical with lessons learned from each cycle informing the implementation of the subsequent cycle. The literature revealed a gap with a shortage of guidance in LPS implementation to steer successful implementation. Early research addressed this gap with the development of 11 guidance principles. Furthermore, a positive relationship was established between consistently high ppc metrics and performance improvement, with steady state PPCs of 70% and above aligning with 20-25% schedule compression as described in case studies 1 and 3, combined with innovative practice development and use. There is limited research demonstrating such a relationship and the research on both projects demonstrated correlation. Furthermore, the issue of the synergetic usage of CPM and the LPS usage was addressed.

The limitations are that further research is required investigating implementation in further sectors.

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