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ARTICLE (PEER REVIEWED)

Evaluating the Efficacy of a Dedicated Last Planner® System Facilitator to Enhance Construction Productivity

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Abstract

Construction unknowingly plans for poor levels of productivity with substantial waste, inefficiency, and rework stemming from a proliferation of non-value adding activities embedded within traditional delivery processes. This approach negatively influences construction's economic and environmental sustainability. Last Planner® System (LPS) is a key tool of Lean Construction (LC) and is lauded as a value-add process that prioritises flow efficiency by addressing workflow variability and waste elimination on construction projects. This research evaluates how the presence of a dedicated knowledgeable and competent LPS Facilitator, enabling a complete LPS implementation, contributes to improved construction flow, efficiency, and productivity.

The study adopted a mixed-methods approach utilising case study design and data collected from a literature review, site observation diary, site documentation analysis, and semi-structured interviews. Limitations exist around small survey size, lack of generalisability, and potential bias of researchers. Findings posit considerable productivity increase; more reliable, predictable, and stable workflow; enhanced team collaboration; as well as accrual of safety, quality, cost, and schedule benefits. Embedding

a knowledgeable and competent LPS Facilitator appears to assist successful implementation of LPS with sectoral and societal value-add opportunities.

Keywords

Lean Construction; Last Planner System; Facilitator; Collaboration; Mindset

Introduction

Construction experiences substantial inefficiency and rework stemming from a proliferation of non-value adding activities and institutionalised wastes embedded within traditional delivery processes and models ([Sarhan, Pasquire and King, 2017](#); [Oakland and Marosszeky, 2017](#)). Traditional construction project management has eluded definition, but [Clough, et al. \(2015, p.309\)](#) describe it as ‘... the judicious allocation and efficient usage of resources to achieve timely completion of all the requirements of the contract documents within the established construction budget’. Additionally, the sector is under considerable pressure to reduce its consumption of material and energy ([Andersson, Buser and Bosch, 2019](#)).

Lean thinking and the tools of LC are postulated as a basis for improving the efficiency and sustainability of the sector ([Koskela, 2000](#); [Sarhan, Pasquire and King, 2017](#); [Sarhan, et al., 2018](#); [Ballard, et al., 2020](#)). LPS is a key tool of LC and is lauded as a value-add process that prioritises flow efficiency by addressing workflow variability on construction projects ([Liu, Ballard and Ibbs, 2010](#); [Mossman, 2019](#); [Ballard, et al., 2020](#)). However, there is a paucity of empirical data underpinning this assertion ([Ebbs, Pasquire and Daniel, 2018](#); [Hamzeh, et al., 2019](#)), as well as a lack of knowledge pertaining to the key drivers of success ([Dave, Hämäläinen, and Koskela, 2015](#); [Daniel, Pasquire and Dickens, 2015](#); [Hackett, Harte, and Chendo, 2019](#)). A clear gap exists regarding the leadership and support required to sustain effective LPS implementations that will truly increase productivity and augment the value offering ([Daniel and Pasquire, 2017](#); [Ebbs, Pasquire and Daniel, 2018](#)). Hence, there is a need to examine the role of the LPS Facilitator, considered a critical success factor and enabler of any Lean implementation. The study evaluates how the presence of a knowledgeable and competent LPS Facilitator enhances construction productivity.

Literature Review

Construction contributes to excessive environmental pollution, production of physical waste, energy consumption, and waste of productive time in its processes ([Johnsen and Drevland, 2016](#); [Weinheimer, Schmalz and Müller, 2017](#); [Liu, Yi and Wang, 2020](#)).

Whilst enhancing construction productivity is critical for the sustained growth and competitiveness of an economy ([Forbes and Ahmed, 2011](#); [Farmer, 2016](#); [Barbosa, Woetzel and Mischke, 2017](#)), Governments and clients are increasingly mandating adoption of construction strategies that consider all sustainability concepts ([Akotia, et al., 2020](#)). Improving construction productivity whilst increasing efficiency and reducing waste will positively contribute to UN Department of Economic and Social Affairs Sustainable Development Goal number 12. However, construction is influenced by adversarial relationships and a deep-rooted inertia to change ([Koskela, 1992](#); [Thomsen, et al., 2009](#); [Pasquire, Daniel and Dickens, 2015](#)). This challenges the introduction of new methodologies and sustainable solutions in the built environment ([Henderson, Morgan and Watson, 2019](#)).

Lean is ‘respect for people’ ([Liker, 2004, p.184](#)), and a ‘...philosophy that focuses on using continuous improvement to eliminate non-value-adding activities in a company’s own production facilities and, eventually, the facilities of key suppliers’ ([Jackson, 2006, p.xi](#)). Lean ‘... contains a promise of tremendous possibilities for improvement and of a solution of the chronic problems of construction’ ([Koskela, 1992, p.64](#)). LC is founded on [Koskela’s \(1992, 2000\)](#) Transformation, Flow, and Value (TFV) theory which

strives for smooth flow with minimum variation, thus positively influencing waste reduction ([Sacks, et al., 2020](#)). Early proponents of LC recognised the necessity to link and supplement traditional construction project management with construction production operations. Specific LC tools were conceived namely, LPS, Target Value Design and Lean Project Delivery System ([Abdelhamid, 2004](#); [Ballard, 2020](#); [Koskela, 2020](#)). LPS is central to the implementation of LC and demands continuous and collaborative effort from all stakeholders for the planning and control of a construction project ([Hamzeh, Ballard and Tommelein, 2009](#); [Howell, Ballard and Tommelein, 2010](#); [González, et al., 2014](#); [Power, Sinnott and Mullin, 2020](#); [Ballard, et al., 2020](#)).

Construction unknowingly plans for poor productivity and studies have found that less than 60 percent of planned tasks are executed weekly ([Ballard, et al., 2007](#); [Liu, Ballard and Ibbs, 2010](#); [Ballard and Tommelein, 2016](#)). Planning problems in construction are accepted and primarily relate to management focus being on control; planning not conceived as a system design; crew level planning being neglected; planning system performance not measured; and planning failures not analysed to identify and act on root causes ([Hamzeh, Ballard and Tommelein, 2009](#); [Mossman, 2013](#); [Daniel and Pasquire, 2017](#)). A key concept in LC is the provision of reliable workflow to work-crews to reduce uncertainty in the delivery process ([Liu, Ballard and Ibbs, 2010](#); [Mossman, 2019](#); [Ballard, 2020](#)); LPS is a major waste reduction and elimination technique that addresses this unpredictability ([Hamzeh, Ballard and Tommelein, 2009](#); [Howell, Ballard and Tommelein, 2010](#); [Hamzeh, et al., 2016](#); [Daniel and Pasquire, 2017](#); [Power and Taylor, 2019](#); [Ballard, et al., 2020](#)). [Ballard and Tommelein \(2016, p.7\)](#) define the function of LPS as ‘the proper work of the system; its jobs’, and note these ‘jobs’ as:

1. Specifying what tasks should be done when and by whom, from milestones to phases between milestones, to processes within phases, to operations within processes, to steps within operations.
2. Making scheduled tasks ready to be performed.
3. Re-planning/planning to complete, to achieve project objectives.
4. Selecting tasks for daily and weekly work plans—deciding what work to do next.
5. Making release of work between specialists reliable.
6. Making visible the current and future state of the project.
7. Measuring planning system performance; and,
8. Learning from plan failures.

Planned Percent Complete (PPC) is a key metric of LPS and measures workflow reliability – a high PPC indicates a well-planned production process with tasks screened in advance, ensuring high workflow reliability between teams ([Ballard, 2020](#)). However, [Ballard and Tommelein \(2016, p.59\)](#) warn against placing too much focus on PPC figures, stating ‘...PPC could be 100%, productivity excellent, and a project still be falling behind schedule’. This emphasises the importance of using all functions of LPS to ensure PPC and productivity are linked to the overall milestone schedule ([Hamzeh, Ballard and Tommelein, 2009](#); [Mossman, 2019](#); [Ballard, et al., 2020](#)). As PPC is positively linked to productivity ([Ballard, et al., 2007](#); [Liu, Ballard and Tommelein, 2010](#)), it is critical for LPS users to ensure that teams executing the work are afforded the greatest opportunity of achieving high PPC ([Power and Taylor, 2019](#)). Additionally, [Weinheimer, Schmalz and Müller \(2017, p.915\)](#) suggest LPS can generate sustainability benefits by its application of core Lean concepts to construction: ‘...process consistency, increasing the reliability of all work and information flows, applying the pull principle, transparency, recognition of obstacles in time, and working in an integrated project team.’

Introducing LPS on a project can influence a variety of social dynamics and promotes cross-trade collaboration deep inside projects ([Ballard, 2008](#); [Mossman, 2013](#); [Fauchier and Alves, 2013](#)), all of which affirms the need for a precise set of skills and competencies for dealing with the softer side of human

interaction ([Chinowski, Diekmann and Galotti, 2008](#); [Daniel, Pasquire and Dickens, 2015](#)). As construction networks are fundamentally based on social networks ([Pryke and Smyth, 2012](#)), [Chinowski, Diekmann and Galotti \(2008\)](#) assert that to achieve the next level of performance in construction it is critical that interactions are managed on a social-collaborative perspective. Effective LPS implementation enables these interactions. The planning process becomes a set of social conversations and promises that engage the team, building trust and commitment, resulting in a more reliable and predictable construction programme ([Fauchier and Alves, 2013](#); [Pasquire, Daniel and Dickens, 2015](#); [Mossman, 2015](#); [Ballard, et al., 2020](#)).

Key literature emphasises the importance of an internal Facilitator, referred to as ‘Process Manager’ by [Thomassen, et al. \(2003\)](#), who can drive and coordinate any change process ([Bhasin, 2012](#); [Daniel and Pasquire, 2017](#)). [Heron \(1998\)](#) defines a Facilitator as one who has the role of empowering participants to proactively learn in an experiential group where learning takes place through the active involvement of each person. Social science researchers ([Parker, Williams and Turner, 2006](#); [Parker and Bindl, 2016](#)) found that proactive behaviour, self-initiated and future-oriented action contributes to multiple positive outcomes. However, despite the obvious benefits [Wu and Parker \(2017\)](#) found that enabling proactive behaviour is challenging to promote as uncertainty exists and outcomes are unknown. A critical role of the Facilitator, therefore, is to create a psychologically safe environment where employees are encouraged to innovate with alternate methodologies and practices ([Heron, 1998](#); [Griffin, Parker, and Mason, 2010](#)). Lean Facilitators need to ‘live the philosophy, and teach it to others’ ([Liker, 2004](#), p.54), and be ‘Lean people who are both

Table 1. Facilitator’s role in Lean and Last Planner System implementation

Author	Reference to Facilitator’s role
Thomassen, et al. (2003, p.65)	‘The process manager is, in a Danish context, a new role introduced at the building site in order to facilitate bottom-up planning by assisting the teamwork between subcontractors. Unlike the project manager, the process manager holds no formal responsibilities (or rights) with respect to economical and legal issues. Thus, the process manager can concentrate on ensuring a good collaboration with, and between, subcontractors. The process manager acts as the coach of the building site.’
Daniel, Pasquire and Dickens (2016, p.29)	‘...the process would not progress if there are no capable and experienced personnel to man the process. On both case study projects the process was internally facilitated. On both projects, LPS facilitation was the primary responsibility of the facilitators which yielded better results. Leaving the process to the team will make no one accountable.’
Daniel and Pasquire (2017, p.7)	‘The human factor on the other hand is concerned with the appointment of a competent facilitators and Lean champions to encourage the process (LPS implementation) on site. Prior research has shown that facilitation is an essential process that needs to be in place for the successful implementation of the process at the project level’. ‘The proactive involvement of the Lean leadership in production planning also increases the buy-in of other stakeholders on the project’.
Ebbs, Pasquire and Daniel (2018, p.725, 731)	‘The case study reported here identified that if senior management insisted on implementing the LPS without sufficient buy-in and leadership from the Project/Site Manager to actively use the LPS, the implementation faded off once the external LPS facilitator stepped back’. ‘Relevant design and/or construction experience of the LPS facilitator is highly desirable in order to build credibility with the team’.

competent and capable of pushing themselves' (Hines, et al., 2008, p.46). Additionally, [Ebbs, Pasquire and Daniel \(2018, p.732\)](#) found that LPS Facilitators require specific knowledge of the nuances of LPS and of construction, noting, '...a Toyota trained expert in Lean with a manufacturing or production background is unlikely to be an expert in LPS'. [Table 1](#) presents references in LC literature to the importance of the internal Facilitator's role in Lean and LPS implementation in construction.

Implementing LPS across construction can be a route to developing the highly desired Lean behaviours that are conducive to greater collaboration and improved team performance ([Fauchier and Alves, 2013](#); [Daniel, Pasquire and Dickens, 2015](#); [Hines, Taylor and Walsh, 2020](#)), both fundamental to improving the sector's productivity. However, as shown in [Table 1](#), a critical enabler of Lean and LPS implementation is the presence of a knowledgeable and competent LPS Facilitator.

Methodology

RESEARCH DESIGN

This study adopted a mixed-methods approach utilising case study design and data collected from a literature review, site observation diary, site documentation analysis, and semi-structured purposeful interviews ([Creswell, 2013](#)). The mixed-methods approach helped to minimise bias as both the quantitative and qualitative models have individual weaknesses which can be compensated by the comparative strengths of the other methods ([Steckler, et al., 1992](#)) and such triangulation enhances the depth, quality, and validity of the research findings ([Bogdan and Biklen, 2006](#)). The research utilised case study design at a single project (Stake, 1998; [Yin, 2009](#); [Yin, 2012](#)). [Yin \(1993\)](#) states that when a researcher is investigating into the "how and why" of a set of events, a case study offers distinct advantages not found in more quantitative research tools. Principles of action research and learning ([Eden and Huxham, 1996](#)) were also applied allowing numerous interventions and augmentations to be implemented ([Bryman and Bell, 2015](#)). The research sources are presented in [Table 2](#).

Table 2. Research Sources

Collection Method	Data Source
Literature Review	Systematic Review of Lean, LC, Change Management, & Sustainability literature.
Observation Research Diary	LPS Facilitator (corresponding author) maintained an Observation Research Diary for the project duration.
Project Documentation Review	LPS PPC Reports, Pull Plans, Constraints Logs, A3 Reports, Project Lessons Learned, P6 Schedule Updates & Reports, Project Monthly Reports. Minutes of Meetings.
Purposeful Semi-Structured Interviews	Client Project Manager, Construction Manager, Civils Supervisor, Electrical Supervisor, 3 X Trade Supervisors (Mechanical, Electrical, Clean Room).

THE PROJECT

The case project resides in the Pharma sector in Southern Ireland. The client employed a consultancy to provide Engineering, Procurement, and Construction Management (EPCM) services. Work packages were executed by civil, envelope (structural steel, cladding, glazing, and external doors), mechanical, electrical, sprinkler, and clean-room contractors. The EPCM company and client agreed to use LPS to coordinate

and manage production operations on-site. Ireland has a strong LC community and many contractors would have awareness of LPS. However, full implementation of all LPS functions in the planning process is challenging to achieve. The intent was for LPS to be maintained by the onsite construction management (CM) team, supported with seven hours LPS Facilitator weekly attendance. As critical schedule milestones were being missed on the project, and as key handover dates loomed closer, both EPCM director and client agreed to position the LPS Facilitator full-time on the project.

DATA COLLECTION, ANALYSIS, AND LIMITATIONS

The LPS Facilitator maintained an 'observation research diary' during the 68-week project duration. This involved recording behaviours, attitudes, moods, and observations from morning huddles, planning workshops, meetings, walks, reviews, and problem-solving sessions relating to the LPS implementation. [Yin \(1993\)](#) and [Mason \(2002\)](#) posit researchers should go to the natural settings where activities occur and observe what people 'really' do in those settings. [Mason \(2002, p.87\)](#) adds if one is '... intending to enter a setting or situation to carry out some form of observation, then you will need to prepare yourself not just for the process and technique of observance, but also for social interaction'. The observation research diary was thematically analysed in accordance with [Creswell \(2009\)](#). Comprehensive documentation data was available, comprising schedule and budget reports, revisions of P6 schedules, contract documents, weekly LPS PPC reports, marked up weekly work plans, reasons for non-completion (RNC), constraints logs, pull plans, and the lessons learned log. By relying on several independent sources of evidence, the researchers were able to increase the construct reliability of the research ([Yin, 1993](#)).

A sequential explanatory approach ([Creswell, 2009](#)) was utilised, with the quantitative data (LPS, PPC, and RNC) being collected weekly as the project proceeded and the qualitative data being gathered after project completion. The qualitative element of the study consisted of semi-structured interviews with a chosen purposeful sample of key project participants who were familiar with the weekly process of LPS on the case site. Seven participants were selected ([Table 3](#)) and agreed to be interviewed. [Strauss and Corbin \(1990\)](#) suggest that if the information is accurately analysed there will come a point where only modest amounts of new material would be found, and saturation would be achieved.

Table 3. Categorisation of Interviewees

Respondent	Category
A	Client Project Manager
B	Construction Management Team (CMT) Construction Manager
C	CMT Civils Supervisor
D	CMT Electrical Supervisor
E	Trade Contractor Supervisor 1
F	Trade Contractor Supervisor 2
G	Trade Contractor Supervisor 3

The interviews were transcribed and analysed using a thematic analysis approach ([Braun and Clarke, 2006](#)); transcribed interviews were read over to create a good understanding and to identify the general ideas and themes related to the research question ([Creswell, 2009](#)). Inferences drawn from the emerging themes were checked by triangulation against the literature review findings to check their reliability and integrity ([Steckler, et al., 1992](#)).

[Mason \(2002\)](#) suggests a major challenge for interpretive approaches revolves around how researchers can be sure that they are not inventing data or misrepresenting their participants' perspectives. As with any research, this study has limitations pertaining to the small survey size, lack of generalisability, and minimisation and elimination of bias during data collection and analysis stages. These are presented in [Table 4](#), together with their causes and the researcher's approaches to mitigate the effects of these limitations.

Table 4. Research Limitations and Mitigations

#	Limitation	Cause	Mitigations
1	Small survey size	Requirement for detailed insight into the case	Use of several data collection methods (literature review, observation, interviews, documentation review). Research extends over 68 weeks, covering project commencement to construction close-out.
2	Lack of generalisability	Single case study	Single case project & generalisability not the main concern. Tellis (1997) cites Hamel, Dufour, Fortin (1993) and Yin (1993) who argue that the relative size of the sample, "...whether 2, 10, or 100 cases are used, does not transform a multiple case into a macroscopic study", thus, asserting single case is considered acceptable once it meets research objectives.
3	Bias of researchers or misrepresentation of perspectives	Corresponding author is member of EPCM company & project team	Corresponding author knowledgeable in research ethics. Co-authors not attached to the EPCM company or project, allowing them to take a more detached and independent view of the case and mitigate the temptation to exaggerate the success of the work. Independent sources of evidence increased the construct reliability. Triangulation ensured documentation data validates qualitative interpretations. Research findings peer reviewed.

Findings and Discussion

LPS FACILITATOR'S ON-SITE PRESENCE

At project commencement both EPCM and client agreed to utilise LPS to schedule production operations on-site. [Figure 1](#) presents data illustrating the correlation between increased LPS Facilitator presence and higher and more stable PPC. (Note the dip in PPC at WW-50 was impact of 'Anticyclone Harmut', a major snowfall event).

[Figure 1](#) illustrates erratic and unstable PPC from work week (WW) -01 to WW-28 during the LPS Facilitator's part-time (seven weekly hours) presence. The LPS Facilitator's presence increased to 20 hours weekly until WW-40 and a corresponding increase and stability of PPC is evident. The LPS Facilitators increased on-site presence from WW-41 until full-time from WW-48 also aligns with consistent and higher weekly PPC figures and reinforce recent LC research findings ([Mossman, 2015](#); [Daniel and Pasquire,](#)

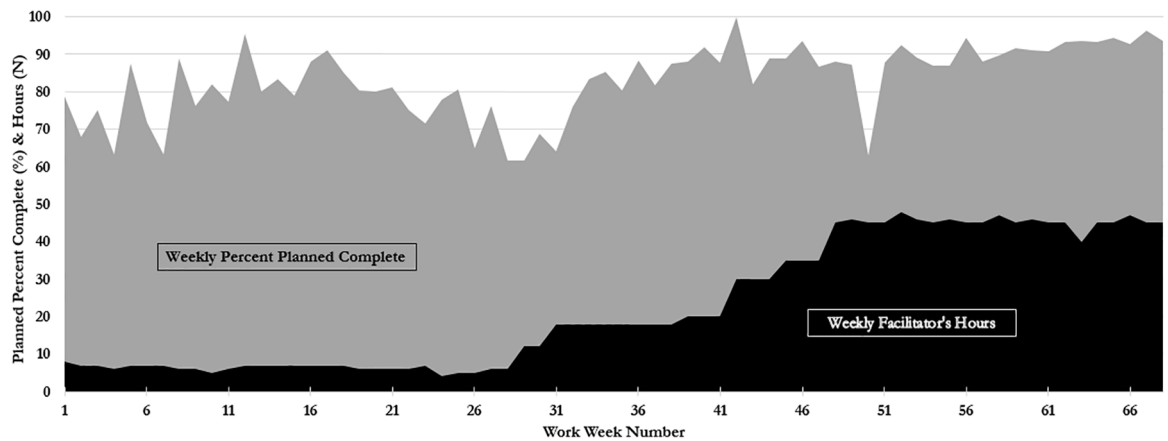


Figure 1. PPC and LPS Facilitator hours correlation

[2017; Ebbs, Pasquire and Daniel, 2018](#)) that facilitation is essential for the successful implementation of LPS at the project level.

IMPROVED PPC AND STABLE WORKFLOW

In [Figure 2](#) weekly PPC is contrasted against a desired PPC figure of 85 percent as mature LPS implementations strive to consistently achieve over 85 percent PPC (85% PPC was used as a 'goal' in a case study cited in [Ballard, Hammond and Nickerson, 2009](#)). The darker shading in [Figure 2](#) indicates the extent of the substandard performance (sub 85 percent) of the planning system with only part-time LPS Facilitator involvement. This poor performance represents waste, inefficiency, productivity loss, and value lost to the trade contractors, client, the sector, and ultimately to society.

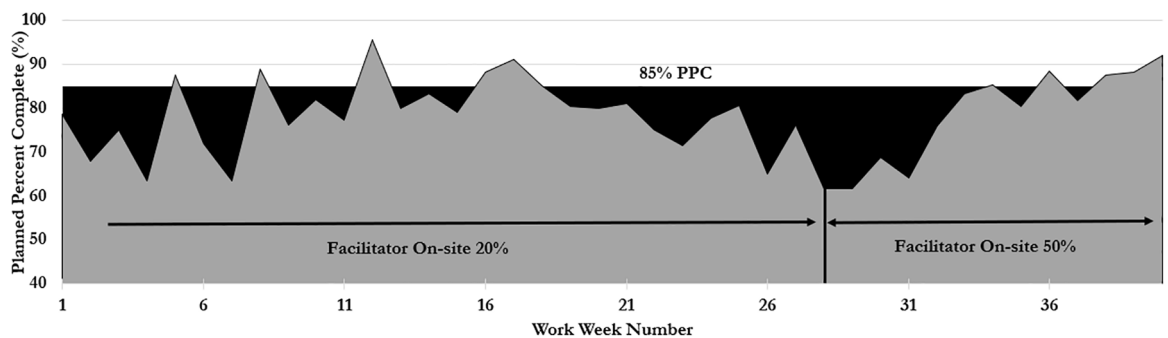


Figure 2. PPC during LPS Facilitator part-time presence

[Figure 2](#) illustrates a positive correlation between greater and more reliable PPC and increased LPS Facilitator presence. Average PPC over WW-01 to WW-40 was 78 percent, falling below the desired 85 percent. The erratic weekly 'see-sawing' of PPC, ranging from 62 percent to 92 percent represents irregular workflow and contributes to negative and costly impacts to contractors work execution. Poor PPC over weeks 28 to 31 results from the LPS Facilitator 'slowing down to speedup'. Analysis of recent reasons for non-completion (RNC), rigorous pull planning, deep constraints identification, and strict admittance of only 'sound and constraint free' tasks onto the WWP took three weeks to fully implement. (Notably, the highest impacting RNC of tasks up to week 28 was 'poor planning / coordination').

The study established an overlap and dependency between the LPS Facilitator and Construction Manager (CM) roles; both need to understand and support each other and ensure their objectives are aligned. Interviewee D suggested “...the LPS Facilitator must be familiar with the project to ensure that all parties are speaking the same language and that everyone is at the same level of understanding and knowledge on the project”. This common and shared understanding (Mossman, 2015; Pasquire, Daniel and Dickens, 2015) is critical to clarifying the ‘Conditions for Satisfaction’ for the next customer in line, while also maintaining the implementation process as, when the LPS Facilitator wasn’t on the case site, “there was no ownership or accountability for LPS and it fell apart” (interviewee D). This finding supports Ebbs, Pasquire and Daniel (2018, p.725), who noted ‘...the implementation faded off once the external LPS facilitator stepped back’. Interviewee C posited the LPS Facilitator “...is as important to the project as the CM”. The importance of having knowledge of construction and its nuances is critical; interviewee B suggested the LPS Facilitator should be sufficiently knowledgeable to act as a “wing-man/supporter” for the CM. Interviewee C commented “...the LPS Facilitator changed a lot when he came on board full-time. He was firm and consistent; he challenged poor performing Last Planners and contractors; he knew construction and was able to call-out persons who were not reporting honestly”.

Figure 3 illustrates enhanced PPC consistency for the duration of the dedicated LPS Facilitator’s site presence.

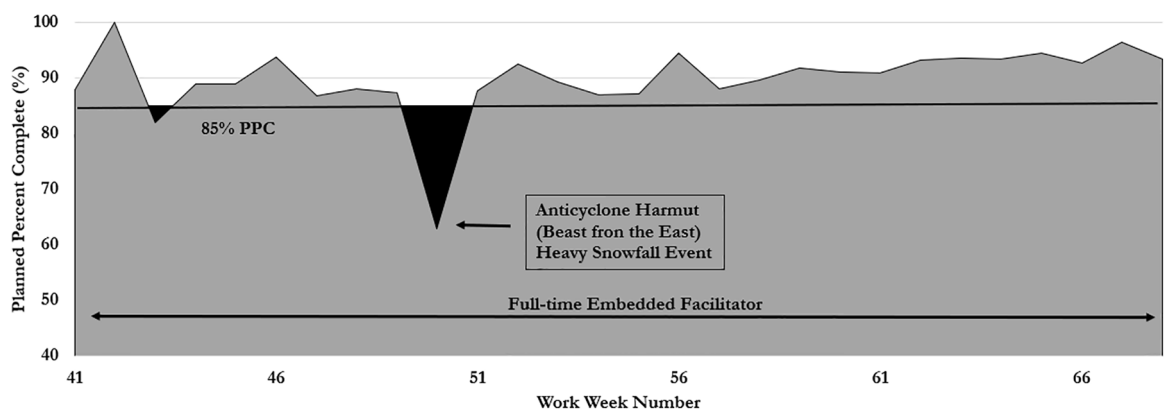


Figure 3. PPC during LPS Facilitator’s full-time presence

The findings confirm the resulting stability, reliability, and predictability aligning with the LPS Facilitator’s full-time presence allied to a complete implementation of all functions of LPS. The darker shading again indicates where PPC fell below 85 percent. Average PPC in Figure 2 (part-time LPS Facilitator) was 78 percent and average PPC in Figure 3 (dedicated LPS Facilitator) was 90 percent. This 12 percent improvement in average PPC is directly related to the LPS Facilitator’s presence and insistence on a complete LPS implementation. Also evident from Figure 3 is the consistency of PPC over time which contributes to predictable, reliable, and even flow, minimising waste while adding value. Interviewees noted that past projects had more reactive ‘fire-fighting’ in their execution; LPS brought a structured approach to planning and coordinating activities on the case project. Interviewee A commented, “...it is the best site coordination methodology that I have encountered”. Because of the weekly structure introduced and coordinated by the LPS Facilitator, the LPS coordination meeting became standardised; it was this feeling of routine that indicates the success that develops from the consistency and reliability of the weekly planning process. The success of this structure was evident when interviewee B noted “...less reactionary planning and fire-fighting means there is also less rework. LPS certainly saved 10 to 20 clashes between trades per week”.

INCREASED PRODUCTIVITY

The PPC trend in [Figure 3](#) shows reliability and consistency over the dedicated LPS Facilitator's presence. A major snowfall event in WW-50 had a nationwide impact and the site was closed for three days causing PPC to drop to 63 per cent. However, schedule impact of the event was minimised as priority work tasks were highlighted on the WWP; attention was focussed on these at the expense of less critical tasks. The 12 percent increase in average PPC is a critical finding, as many researchers point to the positive correlation between PPC and productivity. [Liu, Ballard and Ibbs \(2010, p.240\)](#) established '...PPC and Productivity are positively correlated. As the PPC value increases, productivity increases as well'. The 12 percent PPC increase over the final 28 weeks (dedicated LPS Facilitator presence) of the 68-week project confirms increased productivity for this challenging phase of the project. As missing key milestones earlier in the project led to the dedicated LPS Facilitator's appointment, the reduction of the completion schedule from 31 to 27 weeks correlates with the PPC and productivity increase justifying the LPS Facilitator's input.

The study found that traditional methodologies of pushing and forcing tasks into production workplans without prior constraint identification and removal, and consideration of flow between activities and trades were contributing to 'snow-ploughing' of activities on the schedule. This manifested in the form of unreliable and unpredictable PPC, representing an absence of key LC tenets of creation of flow, the limitation of variability ([Ballard, et al., 2007](#); [Liu, Ballard and Ibbs, 2010](#)), and securing reliability and predictability in the planning process ([Hamzeh, Ballard and Tommelein, 2009](#); [Ballard and Tommelein, 2016](#); [Mossman, 2019](#)).

In line with TFV theory, the LPS Facilitator placed considerable emphasis on trades understanding work as a flow system and consistently sought, through personal conversations and Gemba walks, to develop planner's thinking towards consideration of the next trades in the handoff process; emphasising the criticality of the quality and timing of these handoffs. This optimisation of workflow is a critical enabler of LC, contributing to variation reduction and consequent higher productivity.

SUMMARY OF KEY FINDINGS

The key findings from the study are summarised in [Table 5](#).

Benefits accrued from the 'hard' tool-focused implementation of pull planning, constraints identification, lookahead planning, weekly work planning, and learning from RNC. However, the mood of the site also changed, and interviewees refer to this change as being a critical turning point on the project, highlighting the importance of the 'softer' aspects of LPS implementation. Positive behavioural and 'mood' change was witnessed when all stakeholder's voices were listened to, and participation was encouraged. [Flores \(2016\)](#) distinguishes between unproductive moods and those that are conducive to learning behaviour, adding the key to generating moods of challenge, confidence and ambition is to understand that people create the future in the commitments they make to each other and the actions they take together. Leading change is an essential attribute for any Facilitator, as numerous authors ([Ballard, et al., 2007](#); [Hamzeh, et al., 2016](#); [Ebbs, Pasquire and Daniel, 2018](#)) suggest LPS Facilitator's must motivate people to adopt Lean principles while navigating them away from their perceived safety of traditional methods of construction delivery.

The creation of a 'project team' mindset fostered a cooperative and collaborative climate on site which aligns with numerous authors ([Hamzeh, Ballard and Tommelein, 2009](#); [Mossman, 2015, 2019](#)) who posit a key component of organising production on site is the coordination and active negotiation with trade partners and project parties. The study noted increased trust between some contractors who forged fruitful and productive working relationships, collaboratively designing operations while generating their weekly work plans, supported, and encouraged by CMT supervisors who had subscribed to LPS. This aligns with [Ballard, et al. \(2007, p.356\)](#) who suggests '...senior managers, including the facilitator of the implementation

Table 5. Key Findings from the Study

Themes	Findings
LPS Facilitator	LPS Facilitator was critical to project success by introducing a weekly LPS structure; enabling change from traditional working practices; contributing to increased and stabilised PPC; and, enhancing productivity. More reliable workflow and predictability in schedule adherence.
LPS functions	Entire suite of LPS Production Planning and Control functions were implemented. (Milestone, Phase, Lookahead, Commitment Planning, & Learning & Action)
PPC	The dedicated LPS Facilitator's presence positively contributed to 12% PPC increase over final 28 weeks of the project
Productivity	Higher PPC and analysis of RNC resulted in smoother workflow and increased productivity. Average PPC increased from 78% to 90% during the LPS Facilitator's presence.
Team Behaviours & Alignment	Improved engagement with LPS process with positive behavioural and project mood-change. Leaders and project sponsors modelling and supporting Lean behaviours was critical enabler of engagement. Common and shared understanding of project goals.
Safety, Quality, Cost, Schedule	Improved safety, quality, & cost control arising from improved lookaheads, weekly, & daily coordination. Creation of a 'single project mindset' enabled a collaborative approach to closing-out the project. Completion schedule reduced from 31 to 27 weeks.

effort, must be able to put their egos aside and support changes even when they think they have a better idea'.

Trust-based alignment of the team is fundamental to construction improvement at both micro and macro level. Interviewee D suggests "...more conversations and talking is essential rather than damaging emails or finger pointing. The LPS Facilitator must have the necessary skillset to bring contractors to account while also not using the system as a stick to beat trades up". [Ballard and Tommelein \(2016, p.62\)](#) posit 'Making commitments publicly promotes care in making commitments and increases efforts to deliver on commitments that are made. It also increases collaboration between trades, willingness to share assumptions, best path forward, coordination, and general quality of the work'.

Despite numerous variables that could also contribute to the increased productivity, the findings attribute the contribution of the knowledgeable and competent LPS Facilitator, ensuring a complete implementation of all functions of LPS, as having the greatest impact on enhancing PPC and productivity. [Table 6](#) proposes lessons identified and improvements the EPCM company will implement on future projects.

The study determined that client, CMT, and trade management must engage with LPS as this will enhance success by ensuring the entire team is aligned in a collaborative working environment. Interviewee B commented, "...commitment must be shown by those in charge if you are to convince others to take part". The importance of non-bias is critical as interviewee G suggested when the process "...was run by CMT with no dedicated LPS Facilitator the preference was given to the contractor with which the person running the meetings has a background. (For example, a CM with mechanical background may favour completion of mechanical tasks over other trade's tasks). An independent LPS Facilitator should have a non-biased neutral approach with one end-goal of completing the project on-time and within schedule". This highlights

Table 6. Lessons and improvements identified

Lessons	Improvements
Time allocated for the LPS Facilitator	LPS Facilitator must be allowed time to educate, train, coach, & mentor all parties in the concepts of LC and the principles of LPS. Companies should invest in developing their own dedicated internal LC/LPS Facilitators.
Training of the team	Members of the project, design team, and supply chain must be educated on Lean concepts and the principles and functions of LPS. A 'Lean mindset' should be encouraged amongst the project team with continuous improvement and learning from failures becoming part of standard weekly work.
Involvement of design in LPS	LPS must be used in the design process. An end-to-end project LPS implementation would involve both upstream and downstream players. Next-customer awareness must be developed within the design team. CMT awaits design's deliverables; commitments and promises must be adhered to. Understanding a common language around commitment must be encouraged.
Commitment of Client and Senior Management	Project sponsors must show visible support and commitment to the LPS process.
Team behaviours and Leader Standard Work	An LPS weekly cycle and routine should be developed and applied with Leader Standard Work enforcing behavioural alignment within the project team.

the importance of the 'Respect for People' tenet of Lean and the necessity for the LPS Facilitator to indoctrinate 'Lean behaviours' in the LPS team (Fauchier and Alves, 2013; Pasquire, Daniel and Dickens, 2015). It should be acknowledged that the team had progressed with their initial LPS implementation; the LPS Facilitator reinforced the process and was a critical enabler of successful implementation of *all* functions of LPS. The accruing consistent and reliable PPC correlates to even and optimised workflow and increased productivity; the project's investment in LPS facilitation is therefore worthwhile and justified.

Conclusion and Future Research

This study examines the role of the LPS Facilitator, considered a critical success factor and enabler of any Lean implementation, and evaluates how the presence of a knowledgeable and competent LPS Facilitator enhances construction productivity. The presence of the LPS Facilitator appears to substantially improve project success as introducing a weekly LPS structure, ensuring the entire suite of LPS production planning and control functions were implemented, and positively contributed to increased PPC, smoother workflow and increased productivity. Project sponsors (clients and owners) must show visible support and commitment to the LPS process. Sponsors, design teams, and contractors must ensure the LPS Facilitator is allocated time to educate, train, coach, and mentor all parties in the concept of Lean and LC and the principles of LPS.

The core Lean principles of Value, Value Stream, Flow, Pull, and Perfection, allied to the foundational theory of LC (TFV) must become the core element of the 'new culture' of construction project delivery. Construction must focus on optimising the 'whole' project; the adoption of a sector-wide 'Lean and Growth mindset' would facilitate the adoption of other Lean tools, for example Takt and Scrum, which would

complement LPS and lead to a focus on flow efficiency and improved design of the production process, leading to better validation of project milestones. This paper contributes to Lean literature and to academic and practitioner communities by presenting case study evidence from a live construction project. Companies should invest in developing their own dedicated internal LC/LPS Facilitators as the development of a 'Lean mindset' must be encouraged amongst the project team; continuous improvement and learning from failures should become part of weekly work.

Further research is proposed towards developing a Lean culture of continuous improvement within the end-to-end construction delivery process; towards aligning the project team around an agreed interpretation of the Value proposition; and, in the establishment of a collaborative working environment and Leader Standard Work implementation on construction projects. Examination of how improving the efficiency and productivity of the construction sector can contribute to wider societal economic, environmental, and sustainability objectives also warrants further exploration.

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